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Notified in
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October,
1936

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Field Engineering

Vol. II

(ROYAL ENGINEERS)

1936

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By Command of the Army Council,

H J Creedy

The War Office,
31*st October*, 1936.

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GLOSSARY OF TERMS

Abatis.—An obstacle formed of trees or branches of trees picketed to the ground, with their points towards the enemy.

Batter.—The slope of the face of any earthen, stone or masonry structure which is not vertical.

Baulk.—A timber beam, or road-bearer of a military bridge.

Bay.—The distance bridged by one set of baulks or road-bearers. (*See* Fire bay.)

Berm.—The distance between the edge of an excavation and the mound formed of the excavated earth.

Bight.—The portion of a rope used double when the ends are not available.

Bituminous emulsion.—An emulsion of bitumen in water. (*See* Emulsion.)

Bivouac.—A camp without tents or huts.

Borrow-pit.—An excavation from which earth is taken for a particular purpose, *e.g.* building a breastwork.

Breastwork.—A defence work of which the greater portion is above ground level.

Butt.—The thick end of a spar.

Calibre.—The diameter of the bore of a gun in inches not counting the depth of the grooves.

Camber.—A girder or bridge is said to have camber when it is higher in the centre than at the ends. It is given in order that the girder or bridge may be flat when under full load. Otherwise the deflection caused by the load would tend to make the bridge sag. A camber of 1 in 30 means that the rise in the centre is $\frac{1}{30}$ of the half span.

The term is also applied to the cross section of a road in order to facilitate drainage of surface water.

Camouflage.—Any artificial means employed to deceive the enemy's visual or photographic observation from the ground or from the air.

Catchwater drains.—Drains made on the hillside above a road to intercept the storm water running down the hillside.

Chess.—A specially prepared plank which forms the decking of a pontoon bridge.

Cleat.—A small piece of wood fixed to another to form a support or stop against movement.

Coat.—A single application of material to a surface.

Command.—The vertical height of the crest of a work above the ground level or above the crest of a neighbouring work.

Communications.—Roads, railways, waterways and air routes.

Consolidation.—Making captured ground secure against attack by careful organization of the troops and by the provision of protection.

Cover.—Concealment from view or protection from enemy projectiles.

Crest.—The highest point of a parapet, usually the intersection of the superior with the interior slope.

Culvert.—A structure for the purpose of carrying traffic over a gap in a roadway measuring less than 12 feet in clear span. If the span exceeds 12 feet, it is called a bridge.

Dead ground (or water).—Ground (or water) over which observed or unobserved fire cannot be brought to bear.

Dead load.—A stationary load which is applied continuously to a structure.

Defended post.—A group of trenches or organized shell holes, etc., allotted for defence by a section of infantry or corresponding unit.

Defended locality.—An area of ground organized for defence by a definite unit, such as a platoon, company or battalion, and consisting of a system of mutually supporting defended posts, sited so as to cover all ground to the front, flanks and rear of the locality with fire.

Defensive system.—Works which comprise the complete organization of defence.

Defilade.—The adjustment of the levels of the crest and interior of a work to secure cover for the defenders.

Depots.—" General establishments " in which personnel, animals, supplies, stores or ammunition are held and dealt with in bulk. They are controlled by G.H.Q.

Detonator.—A small amount of very high explosive in a container which can be fired by ignition to explode a charge.

Direct laying.—The method of laying a gun by looking at the target over or through the sights.

Dog.—A bar of iron of which the ends are pointed and bent inwards at right angles—used for fastening heavy timbers together.

Drift bolt.—A specially made long iron spike, up to 50 inches in length and 1 inch in diameter, used for securing heavy timbers together, particularly members of squared timber trestles.

Dug-out.—An underground chamber or passage.

Dumps.—Small collections of supplies, stores or ammunition accumulated temporarily for some particular purpose.

Embrasure.—The aperture in the wall of an emplacement through which a gun fires.

Emulsion.—A mixture of two liquids in which minute globules of one are held in suspension in the other through the action of an agent known as an emulsifying agent.

Enfilade fire.—Fire which sweeps the position from a flank.

Fascine.—A long bundle of brushwood used for revetting, road making, etc.

Field of fire.—An area of ground which any unit or weapon can cover with fire.

Fire bay.—A length of trench from which it is intended to deliver rifle fire.

Formation.—The subsoil shaped to receive a railway or road.

Forward (or covering) zone.—That portion of a defensive system, in position warfare, which is in advance of the main zone.

Frame.—A structure used in underground work consisting of a top sill, bottom sill and two legs.

Frontage.—The extent of ground covered laterally by a body of troops.

Frontal fire.—Fire the line of which is perpendicular to the front of the target.

Gap.—With reference to bridging, that portion of a river, canal, sunken road, ditch or other obstacle over which a bridge is made.

Glacis.—The ground round a work within close rifle fire, sometimes formed artificially. A term used to describe an even natural slope.

Gradient.—The degree of steepness of a slope. A gradient of 1 in 30 means a rise of 1 foot vertically for every 30 feet of horizontal distance. Sometimes expressed as a percentage. A gradient of 10 per cent. means a 10 foot rise for every 100 feet of horizontal distance.

The *maximum gradient* is the gradient that must never be exceeded.

The *ruling gradient* is the gradient within which the engineer will endeavour to design the road, railway, etc., but from which he may be forced to depart for short stretches.

Grazing fire.—Fire which is parallel or nearly so to the surface of the ground.

Ground sill.—The bottom member of a frame or sett used in work underground. The bottom member of a trestle.

Headcover.—Protection against frontal or oblique fire for the heads of men when firing over a parapet.

Helve.—The handle of a pick-axe or felling-axe.

High angle fire.—Fire delivered from guns and howitzers at angles exceeding 25 degrees.

Keep.—A work within the system of defence of a defended locality, and distinct from it. Commanding a field of fire within the outer defences with a view to assisting in their recapture in case of need.

Kerb.—A raised boundary at the sides of a road.

Lead (pronounced **Leed**).—Any wire used to convey an electric current.

Live load.—A load which is suddenly applied to a structure or part of a structure with an impact, producing stresses in excess of those due to its weight when at rest. (*See* Deal load.)

Main zone.—That portion of a defensive system, in position warfare, in which the commander decides to fight out the battle and break the enemy's attack.

Oblique fire.—Fire, the line of which is inclined to the front of the target.

Observation post (O.P.).—A position from which the fire of a battery or a smaller unit or artillery is observed, corrected and controlled.

Overhead cover.—Protection, by means of a roof, against splinters, shells or bombs.

Parados.—A bank of earth constructed to give protection against reverse fire, and the back burst of high explosive shells.

Parks.—Collections of personnel, animals, supplies, stores or ammunition placed by G.H.Q. at the disposal of subordinate commanders. Administrative records are kept of receipts and issues.

Primer (except **artillery**).—A specially prepared nature of high explosive which acts as the medium of detonation between the detonators and the demolition charge.

Profile.—The outline of the section of a work at right angles to the crest line.

Rear position.—A separate defensive system some miles in rear of the leading system which can be occupied in the event of the leading system being captured by the enemy.

Redoubt.—A field work entirely enclosed by a parapet giving all round fire.

Relief.—A party of men who are on duty or who work for a given length of time. This term is used colloquially to express the length of time for which the party works.

Retrenchment.—A system of trenches sited to form a second, though not necessarily a separate, line of defence, usually to reduce the number of rifles required in the front line.

Reverse fire.—Fire directed against the rear of the position. A line of troops or defences thus attacked is said to be "taken in reverse."

Sangar.—A parapet composed of dry-built stone wall.

Sanitation.—The practical application of certain well-established laws with regard to the preservation of health and the prevention of disease.

Sap.—A trench dug by men working at the bottom and constantly extending the end towards the enemy.

Scarify.—To loosen and disturb the surface superficially.

Scrim.—A light, coarse, very open-meshed canvas material.

Scupper or Irish Bridge.—A broad shallow channel to take the drainage water across a road; usually paved with stone setts.

Searching power.—The power of a projectile to reach a target behind cover; it varies with the range of the weapon, the slope of the ground and the angle of descent of the projectile.

Sett.—A term used by miners for a frame or case.

Sett.—Shaped blocks of stone used as a road surface for heavy traffic.

Shelter.—A roofed area giving cover from weather, splinters, or shells.

Slope :—

Interior.—The inner slope of a parapet extending from the crest to the fire step.

Exterior.—The outer slope of a parapet from the exterior crest to the ground level.

Superior.—The slope of the top of a parapet immediately in front of the crest.

Span.—The horizontal distance between the supports of a bridge from shore to shore is called the total span.

Spike.—A large nail of heavy section from 5 inches to 10 inches long.

Spitlock.—To mark out a line on the ground with the point of a pick-axe.

Spoil.—The material resulting from any excavations.

Spreader.—A piece of timber nailed along the top sill or ground sill of a mining frame to prevent the sides from being forced inwards.

Super-elevation.—The raising of the level of the outside edge of a road at a curve so as to facilitate the movement of fast vehicles.

Tactical locality.—An area of ground (*e.g.*, spur, wood, village, etc.) which from its nature or from its position is of particular tactical importance, the capture of which by the attack would cause loss of "observation" or of neighbouring ground, or would provide a covered approach into the position, or would in other ways facilitate the further prosecution of the attack. Such a locality will usually be chosen as the site of a "defended locality."

Task.—The amount of work to be completed by a man, or party of men, during one relief.

Trace.—The outline of the plan of a work on the ground.

Traverse.—A buttress of earth provided between two adjacent portions of a fire or communication trench for protection against enfilade or oblique fire, and to localize the effect of shell bursts.

Templet.—A pattern, guide or model used to indicate the shape which any piece of work is to assume when finished, *e.g.*, wood laths nailed together to outline the section of a trench or parapet used to check the accuracy of the work.

Top sill.—The top member of a frame, sett or case used in work underground. The top member of a trestle.

Transom.—A transverse bearer or support on which the baulks or road bearers of a bridge rest.

Trenails.—Pegs of hardwood used for jointing heavy timbers instead of dogs or spikes.

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PART I—ENGINEER INFORMATION

CHAPTER I

ENGINEER RECONNAISSANCE

1. Information

1. An engineer commander with a force in the field is frequently called upon :—

i. To put forward technical factors that may affect the commander's decision.

ii. To advise the commander regarding the engineering work required in any operation.

iii. To decide upon detailed plans for the erection of engineering works.

He must therefore be in a position to make an accurate estimate of the capabilities and limitations of the engineer resources available. This estimate is dependent on information.

2. *Sources of information.*—Information is collected gradually from various sources. Seldom will all the information be obtainable from one source. These sources fall into two main groups :—

i. Information collected from intelligence reports, maps, record plans, air photographs.

ii. Information collected from direct reconnaissance.

3. *Information from air photographs.*—A great deal of preliminary information can be obtained from air photographs which may greatly reduce the time spent on ground reconnaissance. With the aid of the stereoscope, vertical heights can be read to about 6 ft. Horizontal distances can be measured to about 10 ft. Reconnaissances of any of the following examples may be assisted by the study of air photographs. River crossings, height of banks and width of gap; roads, railways and cross-country routes; tank obstacles.

Further information on the subject is obtained in Manual of Map Reading, Photo Reading and Field Sketching.

2. Reconnaissance

1. It is seldom that information collected from the first source will supply all the details required by the engineers and this will almost invariably have to be supplemented by direct reconnaissance on the ground.

2. The following are examples of the many kinds of reconnaissance likely to be required in the field: Capabilities of and improvements to roads, railways, cross-country tracks; loading, entraining and detraining points; landing stages and piers; demolitions; river crossings and bridges of all kinds; sites for defensive measures and fieldworks of all kinds; resources of areas in tools and materials; water supply and accommodation; concealment and protection.

3. *Initiating a reconnaissance.*—It is usually advisable for the officer who initiates a reconnaissance to dictate the points on which he wants information, preferably in the form of questions requiring definite answers. He must have a clear idea in his own mind of what he requires to know. He should put his questions in an order of priority and should state when, where and to whom the report is to be handed in.

When he divides the reconnaissance among two or more individuals he must be careful to define their exact reponsibilities. He will either allot to each individual a definite objective, such as one or more bridges, or a particular stretch of road or river or a definite area, in which case the boundaries should be so chosen as to be readily recognizable.

4. *Procedure.*—It is essential for engineer officers and N.C.Os. to be able to carry out an engineer reconnaissance rapidly and accurately. In order to make the best use of the time available it is important to set about the work methodically. The following are some of the preliminary steps which will result in a saving of time.

The officer or N.C.O. should :—

i. Write down the instructions received, and read them over to the initiating officer before he leaves, to ensure that they are correct.

ii. Think over the problems until he is absolutely certain that he understands what is required, and ask about any points in doubt.

iii. Study the map and decide what enlargements, if any, are required.

iv. Obtain all available relevant information before starting out.

v. Carefully plan his itinerary, and time it so that his report will be in the hands of the proper officer at the specified time. A REPORT RECEIVED TOO LATE TO BE ACTED UPON IS VALUELESS; but a report, even if incomplete, received at the proper time, may be of value.

vi. Consider whether any co-operation is desirable, such as whether to ask for guides, orderlies or assistants, and whether any assistance can be given by the preparation of enlargements or preliminary calculations while he is away.

vii. Consider what equipment he requires; for example: pencil, tape, level, map, clinometer, compass, knife, carbon paper, foot-rule and watch.

viii. Consider means of transport.

5. *Points on which information is to be obtained.*—Having written down his mission the reconnoitring officer or N.C.O. should make out a detailed list of the points on which he must obtain information in order to be able to answer the questions asked.

6. Although an engineer reconnaissance is primarily technical, it is most important that its tactical aspect should not be overlooked. Tactical and technical considerations will frequently have a bearing on one another and can never be completely separated.

For example, in the selection of the site of a river crossing, the following tactical considerations may affect the decision just as much as the purely technical ones :—

Knowledge of the enemy's dispositions.
Nature of artillery support.
Facilities for small-arm covering fire.
Concealed approaches for troops, vehicles and bridging materials.

Facilities for deployment on the far bank, and the existence of a suitable bridgehead objective.

On the other hand it is possible that purely technical considerations may rule out a site that is the most suitable tactically. For example :—

River too wide for the materials available.
Approaches too bad for the transport of the materials.
Banks too high.
Current too strong.

7. *Reconnaissance reports.*—

i. Reconnaissances generally take one of the following forms :—

(*a*) A definite question to be answered.
E.g. Is the bridge at .... damaged ? If so, what is the extent of the damage ?

(*b*) Certain data is to be obtained upon which an engineering decision or a project is to be based.
E.g. Reconnaissance of a river for suitable bridge crossing.
Measurements of bridges for demolition purposes.
Resources of areas in materials, tools, etc.

(*c*) A complete project to be worked out.
E.g. The reconstruction of a demolished bridge.
Lay-out of a camp and water supply.
Design of a fortified area.

N.C.Os. are most likely to be called upon for reconnaissance of types (*a*) and (*b*). Officers may have to carry out any type and may be called upon to work out projects from data collected by N.C.Os. or other officers.

ii. In the case of a simple reconnaissance requiring an answer to a question or a mere collection of data the form of the report will be simple.

It should begin with a statement of the object of the report and go on to state the facts recorded as shortly and clearly as possible. Good sketches are a valuable addition to reports as they enable a clear picture to be conveyed in the simplest way.

iii. In the case of a report calling for the consideration of alternative solutions or a report of the nature of type (*c*) the form of the report should follow closely the sequence laid down in Training Regulations, for the writing of appreciations, viz. :—

(*a*) Object.
(*b*) Considerations that might affect the attainment of the object.
(*c*) Alternative plans of action.
(*d*) Plan.
(*e*) Appendices containing the full elaboration of the plan, and including calculations, working drawings, sketches, and details of organization.

The object of writing a report in this order is to ensure clear thinking and to make it easy to read. In the following paragraphs these headings are elaborated in detail, but it must be understood that they will not all apply in every case. Each report must be considered on its merits and only so much of this included as is necessary.

iv. (*a*) Every report should be given a heading preferably on a cover sheet, showing briefly and clearly :—

(i) To whom it is addressed
(ii) What the report is about, *e.g.* " Report on the road from .... to .... "
(iii) The map to which references are made. " Ref. map O.S. 1 in. to 1 mile. ALDERSHOT COMMAND " or " Ref. map 1/20000 Sheet 52."
(iv) The name of the person making the report.
(v) The date and time.

(*b*) The object should be stated clearly at the beginning of the report.

(*c*) Next should be set out any points that have to be considered in deciding upon a plan of action. Only points that really affect the plan should be written down, *e.g.* limitations of time, labour and materials, tactical considerations, technical considerations such as width of river, nature of approaches.

Definite conclusions must be drawn from each point, in order that a plan can be made.

(*d*) Alternative plans of action. Frequently the above considerations will permit two or more plans to be considered. If that is the case the advantages and disadvantages should be set out here and a definite course selected.

(*e*) The plan decided upon should then be summarized. This is probably the most important paragraph in the report and the one to which the officer who initiates the report will turn at once.

It should be a clear summary of the proposals and should state shortly the number of men and the estimated time required to complete the job, if applicable. The time should not be stated in man hours. Where possible a definite time and date should be given. If the starting time is not known state the number of hours work required for the working party recommended.

Anyone reading the report can therefore turn straight to this paragraph and find out what it is proposed to do and how long it will take, without having to extract this vital information from a mass of detail.

All the foregoing paragraphs should be kept as short as possible and free from unnecessary detail.

(*f*) The remainder of the report will consist of such details as calculations, sketches, working drawings, organization tables and lists of stores, etc., or whatever is necessary to fulfil the object of the report.

(*g*) These details should be presented in the clearest possible form, which is usually a sketch, or a tabulation or both. General - rules for describing dates, time, places, roads, areas and boundaries and for drafting messages are given in Field Service Regulations, Vol. II, 1935, Appendix IV.

8. *Sketches*.—The object of a sketch is to present certain information clearly. Unnecessary details should therefore be omitted. The following rules apply to all sketches, however rough :—

i. Every sketch should be complete in itself, because sketches accompanying a report have frequently to be detached and distributed among several persons for action.

ii. The sketch should be as large as the page allows.

iii. Unnecessary details of the surroundings should be omitted but the position on the map of the area sketched must be described. For example, the map-references of a prominent cross roads or bridge may be marked on the sketch.

iv. The correct conventional signs should always be used.

v. There must never be any doubt as to what point a place-name refers.

vi. A sharp HB or B pencil should be used, *never* an indelible.

vii. If corrections have to be made they must be clear. If a figure or word is wrong a firm line should be drawn through it and the correction written above or alongside.

viii. Every sketch, and every page of a sketch that consists of more than one page, must have :—

(*a*) A fully informative title at the top.

(*b*) A scale, both written in words and drawn of such a size, and so divided, as to be useful.

(*c*) The signature, rank and unit of the person who drew it in the bottom right-hand corner.

(*d*) The date and time in the bottom left-hand corner.

ix. In addition, a sketch of any ground must have a north point, marked " true," " grid," " magnetic " or " approx." as the case may be.

9. *Working drawings*.—A working drawing is a particular form of sketch and should usually consist of plan, elevations and sections rather than of isometric or perspective views. It should be simple rather than artistic. Its purpose is to enable a workman to make the object depicted ; it is therefore essential to give the material and dimensions of every separate item (even if drawn to scale) with full particulars of any fastenings.

Dimension lines and arrows should not be so thickly drawn or so placed that they obscure the essential outline or detail.

10. *Lists of stores, tools, etc*.—These should be neatly tabulated and the full description of articles required must be given, so that there can be no question of the wrong length of timber or the wrong type of tool or similar errors being made.

They should be written on separate sheets of paper so that, if necessary, they can be detached and used.

11. *Putting together the report*.—Reports will frequently have to be read in a bad light and in uncomfortable circumstances.

It is essential therefore that every single word and figure should be absolutely clear.

Words and lines should not be cramped together.

Pages should be fastened together in such a way that the whole of each page may be read without undoing the fastenings. The pages should be numbered.

A margin should therefore be left on the left of each page. Pins or clips should be put in along the left edge. Two fastenings are preferable to one as the report is thereby prevented from becoming tangled.

Plans, tables, etc., should be placed so as to read horizontally, folded to the same size as the remainder of the report and fastened securely to the report. If time and the means are available it is an advantage if they can be fixed so that they can be read at the same time as the body of the report where reference is made to them.

An index should be placed at the beginning if the report is a large one.

A good report is one that can be understood and acted upon by another person without any questions having to be referred to the author. This fact must be continually kept in mind when deciding upon how much detail to include or omit.

CHAPTER II

SIMPLE FIELD SURVEYING

3. Measurement of slopes and laying off angles

1. *Slopes* are usually described in field works by fractions, in which the numerator expresses the height, and the denominator the base of the slope. Thus a slope described as 4/1 (*i.e.* four in one) is one in which the vertical height is four times the base (Plate **1**, Fig. 1); whilst that expressed by 1/6 (*i.e.* one in six) is one in which the base is six times the vertical height (Plate **1**, Fig. 2).

To convert angles of slope, given in degrees, into fractions as used in field engineering, a rough rule is to divide 60 by the number of degrees in the angle. Thus 6° = 1 in 10 roughly. This rule should not be used for angles greater than 30°.

2. *Field level.*—In the laying out of field works certain simple geometrical operations may be necessary. The only special instrument employed for the purpose is the field level, which is used for setting off angles on the ground, and for measuring slopes.

The level is shown on Plate **2**.

The limb C, which contains the spirit level, must be opened out first, and afterwards the limb B; these are then joined by a catch at X.

The level is used in the following ways:—

i. As an ordinary spirit level; for this purpose it need not be opened at all (Plate **2**, Fig. 4).

When using as a spirit level, after one reading has been taken, reverse the level. If the bubble does not read the same in both directions, allowance must be made for the inaccuracy of the bubble.

ii. As a square for setting off right angles. The limbs B and C form the right angle (Plate **2**, Fig. 1).

iii. As a protractor, for laying out angles. The limb A is made to coincide with the given line, the point of the arrow head being at the given point. The required angle can then be laid out by stretching a tape from the arrow head over the angle as numbered on limb B or limb C (Plate **2**, Fig. 1).

iv. As a mason's level for setting off any slopes from the horizontal to the vertical. For this purpose the plumb-bob, kept in a recess of limb C, is required. The plumb-bob must be suspended from the brass socket in limb C (near the end remote from the spirit level) and allowed to swing freely, and the level moved until the string coincides with the required angle. The edge of the limb A will then be at the required slope (Plate **2**, Figs. 2 and 3).

When laying off or checking slopes it is important to remember :—

(*a*) To have the bubble on top.

(*b*) To have the long limb A against the slope to be measured.

(*c*) To face the markings on the instrument.

v. One side is graduated in feet and inches and can be used as a 4-ft. rule.

3. The *improvised level* shown in Plate **3** may be found useful. By means of it a series of points A, B, C, D, E, F, G, H, I, on the same level, can be fixed and marked by pegs. Suppose AI is 40 yd. and the difference of level of the drain or trench between A and I is found to be 1 ft., then the fall is 1½ in. each length of 5 yd. ; the bottom of the drain or trench can be graded by measurement from A, B, C, etc.

4. Field geometry

1. In some of the more technical operations of field engineering, such as the construction of bridges and in road and camp work, a knowledge of the following applications of simple geometry in the field will often be of use. No special instruments are required.

2. *To lay out a right angle.*—Let X be a point in a given straight line AB (Plate **1**, Fig. 3), from which it is required to set off a right angle.

From X measure off a distance of 4 units XC along AB. Take a piece of line or tape 8 units long, apply one end to point X, and the other to point C ; find a point in the tape 3 units from X, and, seizing it at this point, draw the bight out to D, till the line is taut, then CXD is a right angle. For example, if 1 ft. is the unit—XC=4 ft., XD=3 ft. and CD=5 ft. The longer the sides of the triangle, the more accurate will be the right angle, and it will be found that when laying out long lines, such as a parade ground, or football ground, the sides of the triangle should not be less than 16 ft., 12 ft., and 20 ft. The largest right-angled triangle that can be laid out with a 100-ft. tape is one whose sides are 24 ft., 32 ft. and 40 ft.

3. *To draw a perpendicular to a given line from a point outside.* Let X be the point outside the line AB (Plate **1**, Fig. 4) from which it is required to draw a perpendicular to that line. Take a tape or cord longer than the perpendicular will be ; fix one end at X, and stretch it taut, so that the other end shall cut AB in C. Drive in a peg at C, find D, the middle point of CX. With D as centre, swing DX or DC round to the position DE, cutting AB in E. Join XE, then XE is at right angles to AB.

4. *To lay off an angle of* 60° *or* 120°.—Let X be the point in the line AB (Plate **1**, Fig. 5) from which it is required to lay off an angle of 60°. Take any point C in AB towards that end of the line from which the angle of 60° is to be drawn. Take a tape or cord twice the length of XC, and fasten the ends to X and C. Seize it at the middle and draw the bight out taut to E. Then the angle EXC is 60° and AXE is 120°.

5. *To bisect a given angle.*—Let ABC be the angle which it is required to bisect (Plate **1**, Fig. 6). In AB take any point D. Fasten the end of the tape at D, and take it round B and back again to D. With the length thus found mark E in BC and make the loose end fast at E. Take the centre of the tape from B and stretch it tight in the position DFE. BF will bisect the angle ABC.

6. *To lay out an angle equal to a given angle.*—Let X be the point in the straight line AB (Plate **1**, Fig. 7) from which it is desired to lay off an angle equal to the angle DEC. In the bounding lines of the angle DEC take any two points D, C, and from X measure XG equal to EC. Take a tape equal to CDE. Put the ends at C and E, and make the tape cover CDE. Holding the tape by the point above D, transfer the ends that were at E and C to X and G respectively, and pull the tape taut. Then the point which had been at D will be at some point F, and the angle FXG will equal the angle DEC.

7. *To find the distance between any two points A and B when it cannot be measured directly.*—From B (Plate **1**, Fig. 8) lay off the line BD as nearly at right angles to AB as possible, D being at any convenient distance. In BD select a point C so that BC is some multiple of CD. From D lay off the angle BDF equal to the angle ABD, and on the opposite side of the

line BD. Make DE of such a length that the point E is in line with A and C.

Then $$\frac{AB}{BC}=\frac{DE}{CD}$$

or $$AB=\frac{BC\times DE}{CD}$$

5. Levelling by means of boning rods

1. It is often necessary in the field to make a rough section of a piece of ground or parapet, or to lay out short lengths of ground at a given slope, as in road making, drainage, etc. For such purposes levelling by means of boning rods may be employed.

2. *Tools.*—The tools required for boning are a field level (Plate **2**) (or a mason's level, or a spirit level with a straight edge), a mallet, pickets, measuring tape, a set of three boning rods, and where great differences of level are met with, a long rod graduated to read feet and inches.

3. *Mason's level.*—The mason's level is shown in Plate **4**, Fig. 1, and can be made by any ordinary carpenter, where a field level is not available.

4. *Boning rods.*—Boning rods are usually made of deal, 3 in. wide and $\frac{3}{8}$ in. thick, and consist each of a long arm, with a head dovetailed on at right angles to it (Plate **4**, Fig. 2). Care must be taken that all of a set are of exactly the same length.

To make a section with such rods, it is usual to select the highest point of the section and there drive in a picket flush with the ground, driving in a second picket on the line of the section with its top carefully levelled to the top of the first picket (by means of the field, mason's or spirit level), and as far away from the first picket as the length of the level or straight edge will allow. (*See* Plate **4**, Fig. 3, A.B.) It is evident then by looking over the tops of the two pickets (A.B.) the depth below the line of sight of any other points (C.D.) on the section could be determined by holding up a measuring rod at those points, and the horizontal distance apart of the various points being also measured, a rough section could be made. To avoid the obvious difficulty of getting one's eye down to the top of the first two pickets (A.B.) boning rods are set up to them, and a third boning rod (or long rod) is set up at the different points (C.D.E.) whose levels are required to be known. The boning rods, being all of the same length, give by their tops a horizontal line parallel to the first line of sight, but 3 ft. (or thereabouts) above it. In the same way a given slope (say 1/10) can be set out (Plate **4**, Fig. 4) by arranging the tops of the first two pickets at the required slope (level A and B, 10 ft. apart, and then cut 1 ft. off the top of B), setting up two boning rods on them, and by means of the third boning rod driving in pickets to show the top of the slope at any required points N.O.P. Again, a continuous slope between any two points can be laid out with pickets, as in Plate **4**, Fig. 5, by putting the first boning rod at F, the second at G, and with the third rod setting up the intermediate pickets.

5. *Taking a section.*—In taking a section it is usual to enter levels, etc., in a book (*see* p. 14).

6. Instruments

1. *Clinometer, pendent (de Lisle's).*—

i. *Uses.*—This instrument is of very simple construction and is used for setting out slopes and gradients required for the rapid lay-out of roads, etc. It is designed for gradients from 1 in 5 to 1 in 50, or for a truly horizontal line if required.

ii. *Description of the instrument* (Plate **5**).—The clinometer consists of :—

(*a*) A ring and link H.
(*b*) A half-mirror M.
(*c*) A heavy semicircular weight W on which is a scale graduated from 5 to 50.
(*d*) A radial arm A with index edge and sliding weight B.

iii. *How to use the instrument.*—For convenience of packing in its case, the mirror is placed in the same plane as the weight, but before use, twist the semicircular weight W through one half turn, so that it lies at right angles to the face of the mirror M.

The weight may lie either in front of or behind the plane of the mirror. In the former position rising gradients will be observed, and in the latter falling.

The clinometer is "set" to any gradient from 1 in 5 to 1 in 50 or dead level, by moving the radial arm until the index edge is against the required gradient. It is then clamped in this position by nut C.

When set for laying out a gradient, the sliding weight B must be pushed inwards as far as possible until it covers the word LEVEL and is against stud S_1. It is then clamped. To read a level gradient, turn the radial arm A back to its

BONING AT ....

Stations (see Plate 4, Fig. 3) (1)	Horizontal distances (2) ft. in.	Height of Back Station (3) ft. in.	Height of Forward Station (4) ft. in.	Rise (5) ft. in.	Fall (6) ft. in.	Above or below datum (7) ft. in.	Remarks (8)
A and B ...	5 0	Datum line (or starting line)					Height of boning rod 3 ft.
C	10 6	3 0	5 1	—	2 1	−2 1	
D	8 2	5 1	6 2	—	1 1	−3 2	
E	7 10	6 2	3 10	2 4	—	−0 10	
TOTALS	31 6	14 3	15 1	2 4	3 2	—	

(Signature)

fullest extent until it comes up against the projection at D. Withdraw weight B until it is against stop S_2, and the word LEVEL appears. In this position the sliding weight B exactly counterbalances the semicircular weight W, and the plane of the mirror is vertical.

To lay out a slope, a staff is required with an adjustable target which can be set at the height of the observer's eye above the ground. The radial arm of the clinometer is set to the required gradient, and the mirror is turned in the necessary direction to give a rising or falling gradient as required. The clinometer is then held at half-arm's length, suspended by the ring. Care must be taken that the link is not catching, and that there is free movement. The foot of the staff will be in the required position when the target, as seen through the triangular opening beside the mirror, is opposite the centre of the observer's eye, as seen reflected in the mirror. (*See* Plate **5**, Fig. 2.)

2. *Level, pocket, Mark IV* (*Abney level*).—

i. *Uses.*—The Abney level is a convenient pocket instrument for measuring slopes for roads, drains, etc., or for laying out slopes at any angle. It reads slopes either in gradients from 1 in 1 to 1 in 10 or else in angles 0° to 90°.

This instrument is capable of more accurate but less rapid work than the de Lisle clinometer.

ii. *Description of instrument* (Plate **6**).—The general appearance is shown in Fig. 1.

The body of the instrument consists of a box, carrying a telescope tube at one end, and a slide with sloping mirror and horizontal wire at the other. This slide may be removed by pressing the stud S outwards, if it is necessary to clean or repair the mirror M or wire. (Fig. 2.)

Care must be taken that the slide is pressed fully in before any readings are taken, as otherwise an index error will be introduced.

The mirror is a highly polished piece of steel, placed at an angle of 45° to the bottom of the box. It is engraved with a horizontal line at its centre. This line, and the horizontal wire, should lie on the line of sight through the axis of the telescope, when measuring a slope by the instrument.

The function of the mirror is to reflect to the observer's eye, through a hole in the top of the body, the image of the bubble suspended above it.

To one side of the body is fixed a vertical arc, graduated in degrees, from zero at the bottom to 90° on either side. Gradients from 1 in 1 to 1 in 10 are also marked ; and in some patterns, "elevation" and "depression" angles are also indicated. (The angles on the half scale nearer to the telescope are "elevation.")

On the other side of the body is a bracket to shield the bubble tube, which is tilted about the centre of the vertical arc by means of the milled nut A, through a worm gearing.

The transverse axis of the tube carries an arm, working over the vertical arc, and graduated as a vernier V, enabling angles to be read to 10 minutes of arc. A magnifying glass is provided for use with the scale.

Gradients are read against their respective EDGES of the vernier arm, *e.g.* if the index of the vernier is set to 45° elevation, the index edge nearer to the telescope will be found to lie against the gradient mark 1 in 1.

iii. *Use of the instrument.*—The telescope T is first directed on the object to which a reading is required, and the object is intersected by the horizontal hair.

The milled head A is then turned—clockwise for an angle of elevation, anti-clockwise for a depression—until the bubble image in the mirror is intersected by the horizontal engraved line, at the same time as the object is intersected by the horizontal hair.

The required angle or gradient is then read off the vertical arc against its respective index.

In effect, the bubble B is always brought to the centre of its run at the instant of coincidence.

To lay out a particular slope is the reverse of the above process.

The gradient required is first set on the vertical arc. The level is then tilted until the bubble is intersected by the line on the mirror. At this instant the horizontal hair will be intersecting a point at the required gradient, as measured from the observer's eye.

When measuring or laying out a slope, the level must be sighted on a sight-vane or other mark, set previously to the height of the observer's eye.

When laying out a slope, the sight vane is moved up or down hill until it coincides with the horizontal wire.

The gradient required is then that between the foot of the staff and the foot of the observer.

iv. *Adjustments.*—The only adjustment necessary with the Abney level is to see that the bubble is bisected by the engraved line on the mirror when the index is set to zero, and the level is on a known truly horizontal surface. The adjustment is made by altering the capstan nuts at either end of the bubble tube.

3. *Sextant, pocket, 3-in.*—

i. *Uses.*—For measuring angles direct between two stations (both vertical and horizontal) to within 1 min. of arc, this being sufficient for all ordinary surveying purposes on which it can be used. As generally made, the sextant's range is 120°, so that when larger angles have to be measured, it is necessary to range on to an intermediate mark and to combine the two angles so found.

ii. *Assembly and description of instruments* (Plate **7**).—

(*a*) Open the small slide at the bottom of the box to allow the removal of two dark glasses from the line of sight.

(*b*) Remove the lid E of the box and fit it on the bottom, thus forming a convenient handle for the sextant.

(*c*) Open the cover plate in the side of the box by pressing the stud F sideways. Withdraw telescope T. The instrument will then appear as in Fig. 1. The sextant can be used without the telescope if desired, by looking through the pin hole in the cover plate.

(*d*) A is the index arm, carrying a vernier scale and moving over the scale B, which is graduated from 0 to 140°, each degree being subdivided at the half degree. The index arm is moved by the milled nut C working through a rack and pinion.

This milled nut is not to be confused with the smaller one K which is the head of an adjusting key, that can be unscrewed when required for use.

D is a reading glass, for use with the vernier. It is kept in position, when not in use, by engaging the spring stud G in a groove in the glass holder.

H is a dark glass, fitting on to the eye end of the telescope, for use during sun observations.

I is a pair of levers for moving two dark glasses—red and green. For sun observations they should be in the down position shown in Fig. 2. For other observations they should be raised towards the scale B, thereby depressing the glasses from the line of sight, through the hole in the bottom of the box.

When packing the instrument away, the ends of the levers must be in the down position before the telescope is pushed into the box. Otherwise it will be impossible to close up the dark glasses.

(*e*) Firmly fixed to the axis of the index arm is a mirror, called the index glass, which has its plane truly perpendicular to the plane of scale B.

In the line of sight of the telescope is another mirror, called the horizon glass, the top half of which is silvered, and the lower half clear. This mirror must be so adjusted that its plane is perpendicular to the plane of scale B, and also parallel to the plane of the index glass, when the index arm is at zero.

Adjustments in two directions can be made by means of the two square screws X and Y in the top and side of the box respectively.

iii. *Use of sextant. For observing horizontal angles.*—The sextant is held in the right hand, with the scale horizontal and the telescope focussed on the left hand object. The milled head C is rotated with the left-hand until the image of the right-hand object, as reflected by the two mirrors, is seen to coincide with the left-hand object, as seen direct through the horizon glass. The coincidence is of the nature of a "line coincidence." The vernier scale gives the required angle.

NOTES.—1. If the sextant is held in the left-hand and the milled head turned with the right, the ray from the right-hand object is apt to be hidden by the right arm.

2. It is important that the observations should be taken to two objects on the same horizontal plane; otherwise too great an angle will be recorded.

To obtain the true angle, it will generally be necessary to choose a subsidiary point directly above or below the right-hand object, to which observations must be taken.

The same remarks apply, of course, to vertical angles, which must be measured in a truly vertical plane. In this case, a subsidiary point is chosen on the same horizontal plane as the upper object, and such that it is vertically above the lower object.

iv. *To observe a vertical angle.*—The sextant is held in the right hand, with the scale vertical, and the telescope directed on the lower object. The index glass is then rotated, by the milled head, until the upper object, as reflected by the two mirrors, coincides with the lower object, as seen direct through the horizon glass. The vernier scale then gives the required measure of arc.

Should it be desired to measure the altitude of the sun, a point on the ground must be determined, by level or clinometer, which is at the same height as the observer's eye, and is also on a line vertically below the sun.

The sun's image is then brought down to this "horizon," and the altitude is read off the scale.

Always see, before commencing, that the vernier reads zero.

v. *Adjustment of sextant.*—When the vernier scale is set to zero, and the telescope is directed on any distant object, the reflected image of this object should coincide with the object, as seen direct through the horizon glass. If there is not coincidence, it must be obtained by tilting the horizon glass until it is parallel to the index glass.

The square adjusting screw in the top of the box moves the image vertically; that in the side moves it horizontally.

After the adjustment, the index should be checked to see that it has not moved from zero, and care must be taken that the key is screwed back in the top of the box.

The best object to use for an adjustment is undoubtedly the sun. Place the dark glass H on the telescope T, and holding the sextant sideways with the vernier at zero, the image of the sun should be seen as a single sharp disc.

However, as the sun is frequently invisible, a well defined distant terrestrial object will often have to be chosen.

The pocket sextant must always be checked for this adjustment before any observations are taken, as the older instruments in the Service are very liable to slip out of adjustment.

vi. *Principle of the instrument.*—The principle governing the division of the graduated arc is that the total deviation of a ray of light after reflection successively at the index glass and the horizon glass is double the inclination of the plane of the two mirrors.

The divisions of scale B are then marked with double the true value of the arc they subtend at the centre of the instrument; *i.e.* double the angle actually moved through by the index arm and mirror from the position of zero; or double the inclination of the mirrors, if they were parallel when the reading was zero.

In Fig. 2 the angle read by the instrument is OPO′. This angle is very nearly equal to OEO′. The difference is IOE subtended at the object by the position of the eye and the centre of the index glass. This angle is called the error of parallax due to the eye not being placed at the point of intersection of the rays from the two objects.

It equals about 3 minutes at 100 yards and becomes less the further the right-hand object is from the eye.

4. *The topo pole.*—The topo pole consists of a staff 4 in. wide by ½ in. to ⅝ in. thick, graduated as shown in Plate **8**, Fig. 1.

It is used for the survey of narrow strips of country to be contoured at a V.I. of 5 ft. or less. It is of particular value in connection with rapid road or railway location. It may be used in conjunction with an Abney level or pendant clinometer both set in the level position, but for fast work a pocket reflecting level gives better results.

The principle on which the pole works is that the centre or zero mark is made at the height of the observer's eye above the ground.

The pole is then graduated at 1 ft. intervals for 5 ft. on each side of the zero mark. Intervals of less than 1 ft. are judged by eye.

It is important to make the zero mark at the centre of the pole, *i.e.*, to make the pole reversible.

To obtain the height of any given point the observer stations himself on a point of known height and directs his level on the pole. If the pole is on ground 3 ft. lower than the observer, a level line of sight from the observer's eye will intersect it at the 3-ft. mark.

For use in contouring a road plan the pole is used on cross-sections squared at 300 to 500 ft. intervals along the preliminary traverse.

Fig. 2 represents a road traverse with two cross-sections. The observer is at A, whose height obtained by running a line of section levels along the traverse is 118·1 ft., the ground slopes up to B and down to C.

He wishes to find the 120 contour first. To do this he sends his assistant towards B, and sights on the topo pole with his level until he reads 1·9 ft. below the zero mark on the pole, *i.e.* the ground at this point is 1·9 higher than A, viz., 120 ft. He chains this distance and plots the contour on his plane table at E; thereafter he moves on to B picking up the 125, 130 and 135, etc., contours.

Similarly, starting from A and working towards C, the 115, 110, 105, etc., contours can be picked up.

This done, the observer moves on to the next cross section and repeats the performance.

The method is particularly useful in dense bush.

PART II—FIELD FORTIFICATIONS

CHAPTER III

ELABORATION OF HASTY FIELD DEFENCES

7. Introduction

1. In mobile warfare elaborate work on field defences is impossible. What can be done in the time and with the materials available will generally be done by the infantry and other arms. As soon as any definite check in movement occurs in battle the need will be felt for concealment and cover. The leading infantry will first construct weapon pits on the line on which they are held up. In order to mislead the enemy as to which are the occupied positions dummy weapon pits or posts may also be constructed. If the check is prolonged these will gradually be developed by deepening and joining up into section posts, platoon localities and so on according to the duration of the check in movement. If a period of position warfare sets in these early defences will gradually be developed into a complete system of trenches organized in depth.

Demands will be made on the engineers for improvements to existing works, the construction of new works and defensive systems, measures to secure better conditions for the troops in and behind the lines, the development and maintenance of communications and preparations for resuming the offensive.

2. The siting, design and maintenance of trenches, the general principles of development of a trench system and the elementary fieldworks which are within the resources of all arms are dealt with in the Manual of Field Engineering, Vol. I (All Arms).

The organization of a position for protracted defence is described in Field Service Regulations, Vol. II. The duties and tasks of the engineers are enumerated in Field Service Regulations, Vol. II, and Engineer Training. Some of the items enumerated are dealt with in this chapter; the remainder will be found in the following chapters of Part II of this volume.

8. Joining up section posts and defended localities

1. In joining up laterally the trace should resemble the original posts as far as possible in order not to give away the actual bays occupied.

In joining up from front to rear one communication trench for each platoon post is sufficient and it should be as direct as possible, but subject to the requirements of defilade, must be so sited as to contribute to the flank defence of the locality. It may be necessary, in order to conceal the identity of platoon posts, to construct communication trenches (C.Ts.) leading to the front between the posts.

As the system gets further developed in depth, C.Ts. will become fewer, one up and one down C.T. for each battalion being usually sufficient as far forward as battalion headquarters.

Any elaborate system of connecting posts must be avoided owing to the quantity of labour required for construction and maintenance, and the confusion caused by a multiplicity of unnecessary trenches.

2. Plate **9** shows a typical platoon post developed from four section posts. The labour and stores involved in the construction of such a post are shown in Appendix II.

3. Plate **10** shows how such platoon posts might be joined up into a company locality in an isolated position. If it were one of a series of localities the principle would be similar but the lines of fire and the wire would be designed in conjunction with neighbouring localities so as to ensure mutual support.

Further development into a complete trench system is merely a continuation of the same principles a stage further with the addition of shelters, dug-outs, observation posts, mortar emplacements and other accessories of trench warfare.

9. Loopholes in trenches

1. Overhead cover is never provided in a trench that is to be occupied as a fire trench. Loopholes may be used to give head cover. All firing by night and to repel an attack whether by day or by night should be over the top of the parapet, but some loopholes will be needed in all trench systems for the use of snipers.

2. Various types of loopholes are shown on Plates **11**, **12** and **13**.

The art of building loopholes so as to make them secure, invisible, and convenient for firing at definite points, requires

most careful study and training. The chief points to be observed are :—

i. They are usually made at night, and therefore the alignment must be sited and marked out by day. They must not be visible from the air.

ii. The work must be completed in one night and all signs of new work must be obliterated before daybreak.

iii. The maximum amount of protection must be given to the firer. A service steel loophole plate, with a metal flap to close the aperture, is the best form of loophole at close quarters.

iv. The recess must give sufficient room to allow the firer to use his rifle obliquely through the loophole from either side (Plate **11**).

v. Loopholes must be concealed from the front, and they are therefore set obliquely in the parapet.

vi. Curtains must be hung at the back of the loophole, so that its position is not disclosed by light showing through it.

vii. Concealment may be facilitated if the exterior slope of the parapet is made irregular, and timber and rubbish of all sorts thrown over it (Plate **13**).

10. Sapping

1. Sapping consists in constantly advancing a trench in the direction of its length by a party who work standing on the bottom of the trench and keep themselves under cover by throwing up a parapet on the exposed flank and end of the trench.

The width of a sap is just wide enough to allow one man at the face to use his tools (Plate **14**, Fig. 1).

Sapping is resorted to when the fire of the enemy is too accurate to do ordinary work, or when it is necessary to establish communication between listening or other forward posts and the front trenches.

The average rate of progress is from 2 to **3** ft. an hour. The man at the face must be constantly changed.

Saps should be wired in on both sides to prevent the enemy from raiding and capturing the occupants.

2. *Russian saps* (Plate **14**, Fig. 2) are tunnels driven from 2 to 3 ft. under the surface in the same way as described for dug-outs and subways in Chapter V. They are made to establish concealed communications between the front

trenches and the forward posts or to provide exits from the former for raiding and assaulting troops.

In position warfare, prior to an offensive, Russian saps are driven forward towards the enemy's trenches so as to enable communication to be established as quickly as possible, when these trenches have been captured. A Russian sap is converted into a communication trench by removing the top sills of the frames and allowing the supported earth to fall in. This earth must be cleared away at once, otherwise the sap soon becomes impassable and the sides of the sap must be prevented from collapsing. The side timbers may be kept in place by screwing home short screw pickets in the side of the sap about three-quarters the height of the sap every **5** ft. and passing an iron rod or pipe through the eyes (Plate **14,** Figs. 2 and 3).

3. *Force pipe.*—A 3-in. pipe fitted with a rocking head is forced through the ground by means of a jack. The apparatus takes up very little space, and can be worked in the front line trench. The method is to force the pipe parallel to the ground at a depth of **3** to 4 ft. It is then filled up with ammonal and exploded when the sap is to be opened. It will not work in rocky or stony ground.

11. Drainage and revetment

1. In constructing new trench systems drainage is of paramount importance.

Excavation of drains should be done uphill and the bottom of the trench graded before work ceases each day, so that pockets formed by unfinished tasks are not left to collect water.

Sumps or soakage pits should not be relied on unless natural drainage is impossible. If a sump ceases to absorb water the sides should be shaved off to remove the particles of silt that may have choked the pores of the permeable stratum. Sumps are of no value in ground where breastworks, instead of trenches, are necessary, as the water is near the surface.

2. To assist drainage the installation of pumps may be necessary. For handworked pumps the garrison supplies the working party: engineers work power pumps.

3. Revetment is dealt with in the manual of Field Engineering, Vol. I (All Arms). In sandy country and in marshy ground revetment may become difficult and call for engineer assistance.

When building breastworks in sandy country there is a tendency, owing to the small angle of repose, to build without keeping the parapet bullet-proof the whole time. This is especially so at night.

12. Defence of craters and shellholes

When mining is resorted to, and large craters are formed, it is generally advantageous to occupy these craters at once, because of the increased observation to be obtained from posts on the lip of the crater.

Two methods are shown on Plates **15** and **16**; they indicate the nature of the work required.

The following points must be attended to:—

i. Each post must be carefully protected with wire.

ii. Shelters must be provided for the men of the post, giving protection against rifle and hand grenades.

iii. The inside of the crater must be watched as well as the outside of the lip. This is done by observation tunnels (Plate **16**).

The posts in the crater must be connected with the trench system by communication trenches.

iv. It is usually impossible to obtain good holding ground for revetment anchorages, and frames such as special deep "A" frames (Plate **17**) must be used; pit props, 6 in. in diameter, are the most suitable material.

13. Obstacles and inundations

1. Tactical obstacles against infantry are likely to require development. Barbed wire is usually the most suitable material but natural obstacles such as marshes and other difficult ground and, where feasible, inundations, should be made to play their part.

2. *Tank obstacles.*—

i. The construction of *tankproof localities* generally involves the combination of natural and artificial tank obstacles. Whatever artificial obstacles can be made available it will be unlikely that they will ever be sufficient to cover the whole front. It will usually be a case of utilizing the artificial obstacles to cover the gaps between natural obstacles. There are more natural obstacles in many types of country than is generally realized.

ii. The *critical height* that a tank cannot climb is the height of the centre of the front sprocket wheel of its track from the ground in the case of a solid obstacle. In the case of soil, etc., liable to flattening some increase must be made.

The following figures should be worked to in designing tank obstacles, but these are liable to modification with the improvement to be expected in tank performance and must be adapted to the actual performance of enemy tanks.

Vertical height of obstacle	3 ft.
A slope greater than	45°
A trench wider than	8 ft.
Water exceeding in depth	3 ft. 6 in.

Trees or stumps not less than 9-in. diameter (12-in. for fir trees) and not more than 8 ft. apart. Plates **18** and **19** show examples of natural and artificial obstacles. Many others can be devised. Rails sunk at least 5 ft. in the ground and having 3 ft. out of the ground, sloping at 45° towards the line of advance of the tank and 8 ft. apart, form a useful obstacle.

iii. Tank minefields are dealt with in Chapter XXIV. A few A.T. mines placed between the obstacles may be effective as tanks caught by them will improve the obstacle.

3. *Road blocks.*—Roads can be blocked effectively in various ways: by cratering, as described in Chapter XXIII, by blowing buildings across them and by felling trees. Armoured cars can be stopped by one or more coils of concertina wire opened out and bent into U shape to fill the breadth of the road; the inside of the U should face the oncoming traffic in such a manner that the wheels of the car enter the open ends of the concertina; the ends should not be fastened in any way.

No rapidly made wire-block will stop a tank. Pits can be dug and will prove effective but they require a relatively large amount of time and labour.

A crater to stop a tank must conform to the measurements stated in para. 2, ii, above, otherwise the tank will crawl in and out again. A crater 6 to 8 ft. deep—15 to 30 ft. wide and using 80 to 100 lb. ammonal is the type of thing likely to be effective, but it must be realized that every case must be treated on its merits, and no hard and fast rules can be laid down.

The effectiveness of all such blocks depends on their being located in defiles and kept under constant observation and fire.

4. *Gaps in obstacles.*—The only gaps required in forward defences are a few small, well concealed exits for patrols.

In rear positions, however, it is important to have plenty of well marked gaps for counter-attacking troops, or in order that troops and guns retiring may not be hindered and delayed under the enemy's fire. Points to be remembered in making these gaps are :—

i. They must be provided with knife rests, wire concertinas, etc., so that, in a withdrawal, they may be closed by the last troops to pass through them.

If a gap is to be closed with knife rests, the ends of the entanglement on each side must be square, so that a complete block is effected (Plate **20**).

The knife rests must be securely anchored to the entanglement or to stout pickets driven into the ground, their inner ends being provided with loops of plain wire with which they can quickly be connected together when in position across the gap.

ii. Gaps for infantry should be provided about every 100 yards. To avoid additional gaps they should coincide with communication trenches where such exist.

They should be zigzagged through the obstacle zone, but should not be too complicated for a mounted man to pass.

iii. Road gaps (*i.e.*, where a road passes through an obstacle zone) are extremely important and must be carefully prepared for blocking (Plate **21**), as they are the weakest points in the obstacle zone.

Where they are numerous the infantry gaps should be made to coincide with them as far as possible, except that in the case of important main roads it is better to make an infantry gap 20 to 30 yd. to one side, so that the passage of infantry may not interfere with the road traffic.

iv. Where sufficient roads and tracks do not exist, special artillery gaps must be made every half-mile; they should go straight through the obstacle zone, should be well marked, and arrangements must be made to leave the trench undug opposite them or to bridge existing trenches; ramps into or out of trenches should not be made, as they become impassable in wet weather.

The obstacles must be protected from damage by guns and vehicles by rows of strong posts on each side of the gap.

v. All gaps must be well marked by :—
  (*a*) " GAP " boards.
  (*b*) Painting the posts white at the side of the gap on the defenders' side.

vi. Every effort must be made to conceal gaps from hostile ground and air observation.

5. *Inundations.*—

i. Inundations form a very effective obstacle against all arms, including tanks, but they are only suitable where passive defence is intended, as once formed they may render the area covered impassable by any but the lightest traffic for long periods.

ii. Accurate information may be collected from civil records regarding the levels of rivers and canals, and the probable effect of inundations on the surrounding country in the neighbourhood of a proposed defensive position. The possibility of inundation should be investigated when military engineer reconnaissances are being carried out.

iii. Inundations on a small scale can sometimes be formed in front of a line when a position is occupied near a stream. The best site for such inundation is one where the bed of the stream has only a slight fall, the sides of the valley being regular and rising rather abruptly.

iv. Inundations are more difficult to cross when ditches are cut chequerwise through the ground to be inundated, and deep pits dug before damming up the stream : a trench plough would facilitate this work. Wire, etc., may also be used with advantage.

14. Machine-gun emplacements

1. *General.*—Machine-gun emplacements in mobile warfare are dealt with in the Manual of Field Engineering, Vol. I (All Arms).

In this volume the more elaborate emplacements constructed by engineers are considered.

Many machine-gun emplacements depend for their security on concealment.

The subject of concealment is dealt with in Chapter VIII and in the Manual of Field Engineering, Vol. I (All Arms).

In the forward area the following must be considered :—

i. Concealment is more important than strength.

ii. Owing to possible isolation, provision for all-round defence must be made. In some cases, such as concrete pillboxes, alternative gun positions might have to be dug outside the emplacement.

iii. A ring of high wire is not advisable, as this would give away the position from the air.

2. *Siting.*—The exact position of the loophole, and the height of the bottom of the loophole above ground must first be fixed.

To fix the height of the loophole, the field of fire must first be cleared through obstructions, such as the parapet, in at least two places.

Cross fire is better obtained from re-entrants than from salients.

3. *Dimensions.*—*See* the Manual of Field Engineering, Vol. I (All Arms).

A floor space of 6 ft. 6 in. by 7 ft. is sufficient to accommodate the detachment.

4. *Design.*—The table should be made of wood to suit the tripod mounting, and sandbags added to take a muzzle point traversing mounting. The space under the table is useful for stores.

Every strong emplacement should be fitted with a traversing mounting. The breadth of the table from front to rear may be reduced from 4 ft. to 3 ft. if a recess is made in the parapet for one leg of the tripod.

Box loopholes should not be fixed to brick or concrete emplacements, as they get easily broken or displaced.

Whenever loopholes are sited low, the ground, for about [illegible] yards in front, should be hollowed out to collect falling debris that might block the line of fire.

Concrete loopholes should be given a brick lining to allow of a slight adjustment in alignment. The loopholes of enfilading guns should be concealed from frontal observation by carrying forward a tongue of parapet, but care must be taken that the tongue in no way masks the field of fire.

Frames with wire netting fixed to the back of the uprights make better revetments than sandbags.

5. *Miscellaneous.*—The parapet adjoining a covered machine-gun emplacement should be built up to the same

height as the roof of the emplacement for at least 20 yd. to either side.

Every strong covered emplacement should have an alternative night firing open position.

Wiring should be laid out to suit machine guns, and when guns are sited low, little or no wire, certainly no stout pickets, should obstruct the fire of the gun.

Unless thoroughly strong emplacements can be built, open emplacements with good shelters near in which detachments and guns can shelter, are probably best.

To remove poisonous fumes, a good ventilating draught should be provided.

Guns sited in the foremost trenches are sometimes subject to capture by the enemy in a raid or in an attack on a large scale. This can be avoided by siting the emplacement behind the parados (*see* Plate **22,** Fig. 1).

The underground dug-out is shared by the infantry and the machine-gun detachment as shown.

6. *Types of emplacements.*—Plates **22** to **26** show details of various types of emplacements.

i. *Champagne type* (Plate **23**) is open but gives dug-out accommodation for the team in addition.

The emplacement itself is merely a rectangular pit with revetted sides. A base is provided over a well giving access to the dug-out below. Emplacements of this type are usually constructed in pairs, communicating with a single dug-out. The distance between the two emplacements should not exceed 35 yards. This type of emplacement is well suited for areas normally liable to shell fire, more particularly in sites under direct observation from the enemy observation posts, as it is invisible to ground observation and easily concealed.

When under direct observation this splinter-proof cover should not be provided, as it may disclose the emplacement.

As their construction involves the use of much material and labour, they should only be used to protect points of special tactical importance. They should be used in preference to concrete emplacements wherever possible.

ii. A reinforced concrete machine-gun emplacement is shown on Plate **24**. For details of reinforced concrete construction, *see* Chapter VII.

iii. For a machine-gun emplacement in a breastwork, *see* Plate **25.**

iv. Plate **26** shows an emplacement constructed in 4 hours, and having the appearance of a traverse.

v. A brick emplacement built in a house is shown on Plate **22,** Figs. 2 and 3. The excavation in front of the wall is for collecting fallen debris without obstructing the fire of the gun.

15. Searchlight emplacements

1. Plate **27** shows the first four tasks in digging a circular emplacement for the short arm projector. Task 4 gives the essential cover. The plate also shows a plan and section of the emplacement fully developed and revetted.

CHAPTER IV

ARTILLERY EMPLACEMENTS

16. General

1. *Classification.*—Gun emplacements may be classed as :—

- i. Concealed (artificially) without any protection ;
- ii. Concealed, with splinter-proof protection ;
- iii. Concealed, with shell-proof protection.

The concealment of gun emplacements is fully considered in the Manual of Field Engineering, Vol. I (All Arms). Shell-proof protection is seldom provided for medium or field artillery ; such protection for heavy artillery is dealt with in the Manual of Military Engineering, Vol. II.

2. *Diagrams* on Plate **28** show the minimum vertical and horizontal dimensions of emplacements of various types of guns.

3. When *time and materials* are available, splinter-proof overhead cover can be provided for the lighter guns and howitzers. The principles of constructing such cover are given in the Manual of Field Engineering, Vol. I (All Arms), 1935, Sec. 43.

Examples of 60-pr. and 18-pr. emplacements are given on Plates **29** and **30**, respectively.

4. *Embrasures and entrances* of emplacements can be protected by methods shown on Plate **31**. The protection can be adjusted according to the switch required. A hung wooden framework (9 in. by 3 in. timber) with six layers of wire netting nailed on in front and four layers behind will also prevent splinters entering the embrasure.

The embrasures and entrances of covered gun pits and splinter-proof shelters must be covered with light removable screens to hide the shadows which are invariably cast.

5. *Reverberation.*—Gun pits constructed of elephant shelters or any gun pit the roof and walls of which are curved, are much more noisy than rectangular pits.

To avoid reverberation, blankets or other soft thick woven material may be hung from the roofs.

The effect can be reduced by making the forward part of the pit curved and the rear part rectangular.

6. *Platforms.*—A platform for any nature of gun or howitzer consists of two parts—a support for the trail and a bed for the wheels. The former is the more important and work should always be done on this first. Both are essential if prolonged firing is to be carried out from the same position and, for equipments which do not carry their own platforms, must be improvised from the material available.

7. *Trail support* (*see* Plate **32**).—This should consist of two parts :—

- i. A fixed support, which may be of concrete or pit props firmly fixed with pickets. It should be circular in shape so that the thrust is always radial to the curve at the point of support.
- ii. A cushion, which may be formed of sandbags, blankets or sacks stuffed with hay or straw.

8. *Wheel bed.*—This may consist of :—

- i. Rubble or brick well rammed.
- ii. Wicker.
- iii. Wood.
- iv. Ordinary earth.
- v. Concrete.

Rubble or brick (at least 1 ft. deep), well rammed, extending the whole width between the wheels is excellent if the ground is not too wet. In the latter case the brick should be packed in boxes of rough wood.

Wicker, fascines or brushwood hurdles, with brick on top, are useful for wet ground as they prevent the gun sinking. Such platforms are, however, inclined to be unsteady and jumpy.

Wood platforms facilitate the man-handling of the gun, are portable, and can be quickly put together. Wood, however, has the disadvantage of being " springy " and thereby causing " jump," but this is not so noticeable if heavy timber is used, such as sleepers, or 9-in. by 3-in. planking (laid double), and carefully bedded.

Wheel guides may be added to keep the gun in its line of fire and prevent " frogging " (Plate **33**). A simple form of wheel guide consists of the tyre of a gun or G.S. wagon wheel spiked to the platform.

6-in. wire nails should not be used in the construction of platforms if iron spikes can be obtained, as the gun tends to tear up planks fixed down by nails. An iron spike about ⅞ in. square and 8 in. or 9 in. long has been found successful. Holes for the spike must be made with an auger.

Ordinary earth, under the best conditions, will only stand a limited number of rounds dependent on the nature and the weight of the gun.

Concrete forms a satisfactory platform if time is available to allow it thoroughly to set; it is useless unless well mixed.

All platforms should, if possible, be continuous decking and not mere wheel tracks. The surface should be hard enough to prevent the spade and trail eye becoming embedded and soft enough to prevent excessive jarring of the carriage.

Circular trail baulks are desirable as straight ones tend to give the gun a side movement with every round, when the trail is not at right angles to the baulk. This can generally be remedied by dogging short pieces of timber together and laying them on the circumference of a circle.

17. Platforms for various guns

1. *Field artillery.*—The cushion for the trail support may be fixed with wire in the angle between the spade and trail eye.

For extended occupation two or three trail supports at varying heights can be prepared for different angles of elevation.

2. *Medium artillery.*—

i. 60-pr. A platform can be made of six pieces of 9-in. by 3-in., 10 ft. long, and four pieces 4 ft. 6 in. long as bearers underneath (Plate **33**).

Another platform used with success is made as follows: Remove 1 ft. of surface earth, cover with two layers of expanded metal and broken bricks on top. A stout wood frame held in place by pickets should be fixed round the bricks to keep them in position.

Plate **34**, Figs. 1 and 2, shows a trail buffer suitable for bad ground.

ii. 6-in. howitzer. A wooden platform consisting of 9-in. by 3-in. planks (Plate **35**) is desirable, and in wet ground is absolutely necessary.

Brick rubble forms a good trail support with a fascine placed on the spade as a cushion as the trail is liable to buckle if the support is too firm.

The rubble requires constant replenishment. In soft ground it may be necessary to place a baulk on the spade to prevent the spade burying itself.

3. *Heavy artillery.*—

i. 8-in. howitzer. A special double-decked platform (Plate **34**, Fig. 3) is desirable and is made as follows: Excavate the ground to a depth of 8 in. and lay six pieces of 9 in. by 4 in. in the line of fire as shown and then ram broken brick between them. Put on the top deck at right angles to the line of fire. This requires:—seven pieces, 9 in. by 4 in., each 13 ft. 6 in. long, and ten pieces, 9 in. by 4 in., each 4 ft. long. The top of the platform is flush with the ground. A small tilt to the front is an advantage. When firing above 35 degrees elevation, the rear end of the buffer strikes the platform unless part of the back of the platform is cut away and a hole dug in the ground.

This platform is serviceable on all kinds of ground when the actual surface of the ground has not been disturbed.

For a spadeless 8-in. howitzer firing with scotches, a three-decked platform (made of 12 in. by 4 in. timber), 12 ft. square, is required.

ii. 9·2-in. howitzers carry their own platforms in the form of baulks, under which brick rubble or similar material should be laid.

CHAPTER V

SHELTERS AND DUG-OUTS

18. General

1. The construction of shelters and dug-outs, for important headquarters is one of the tasks on which engineers are likely to be employed in the initial stages of the defence of a position. If the defence becomes protracted there will be a gradual elaboration of the temporary works and a call for mined dug-outs, shell-proof cover and concrete or tunnelled machine-gun emplacements.

The construction of concrete shelters requires considerable time, labour and material and will usually only be possible in very protracted defence ; it is dealt with in Chapter VII.

2. Three grades of protection can be provided :—

i. *Shrapnel or splinter-proof.*—Proof against shrapnel, machine-gun bullets and small splinters. It can be provided in a halt of a few hours.

ii. *Shell-proof.*—Proof against shells from guns, howitzers and mortars up to 6-in. (150 mm.). It can be provided when troops are held up for several days.

iii. *Heavy shell-proof.*—Proof against 8-in. (200-mm.) shell and heavy trench mortars and against single hits by heavier shell. This would only be provided in protracted defence.

3. Table 1 (p. 37) shows the cover that has in practice afforded protection against a direct hit from the shells specified.

19. Materials

1. The following materials, when available, are used in the construction of protective accommodation both above and below ground.

i. Small corrugated steel shelters.
ii. Large corrugated steel shelters.
iii. Curved corrugated steel shelters.
iv. Troughing plates in 6 ft. and 9 ft. lengths.

TABLE 1.

Degree of Protection	Cover
1. Shrapnel, splinters and M.G. bullets.	1 ft. 4 in. concrete, or 6 in. concrete and ½ in. steel plate, or 12 in. to 2 ft. 6 in. earth with burster, or 10 in. to 2 ft. earth with burster, C.I. sheets, hurdles or planks, or 2 ft. 6 in. earth and a layer of 8-in. logs.
2. Field guns (75 mm.).	9-in. burster and 4 ft. 6 in. earth, or 2 in. earth, 9 in. bricks and road metal, 12 in. earth, 18 in. sandbags with earth, pit-props, planks.
3. 4·5-in. shells (115 mm.).	Turf, 1 layer sandbags with earth, 1 layer 4 in. R.C. blocks, 4 ft. 6 in. sandbags with earth, corrugated iron.
4. Shells under 6 in. (150 mm.).	Mined dug-outs. In shell ploughed earth 24 ft. Wet clay or wet sand 18 ft. Dry hard chalk 18 ft. Dry clay or dry sand 12 ft. Hard chalk 9 ft. Hard granite 6 ft.
5. 6-in. shells.	(*a*) *Mined dug-outs.*— In made earth, 35 ft. In clay, 30 ft. In gravel, 25 ft. In chalk, 20–25 ft. In hard rock, 15 ft. (*b*) *Reinforced concrete.*—3 ft. 6 in., or reinforced concrete 6 in. rails, 9-in. air space. reinforced concrete 3 ft. (*c*) *Mixed cover.*— 3 in. earth, 2 ft. 6 in. burster, 3 ft. air cushion, distributing course, 2 ft. earth cushion, 4 in. splinter course, or 2 layers sandbags filled with stones, 3 ft. earth, 2 ft. reinforced concrete.
6. 8-in. shells (200 mm.).	(*a*) *Mined dug-outs.*— Shell ploughed land, 40 ft. Wet clay or wet sand, 30 ft. Hard dry earth, 20 ft. (*b*) *Concrete and masonry.*— 4 ft. reinforced concrete, or 5 ft. plain concrete, or 7 ft. masonry.
7. 12-in. shells (300 mm.).	(*a*) *Mined dug-outs.*— Shell ploughed earth, 56 ft. Wet clay or wet sand, 42 ft. Hard dry earth, 28 ft. (*b*) *Concrete and masonry.*— 6 ft. reinforced concrete, or 6 ft. plain concrete, or 7½ ft. masonry.

v. Timber frames supporting a roof of rails, steel joists logs, etc.

vi. For mined dug-outs.—

(*a*) Inclines and galleries.—9 in. by 3 in. timber setts; uprights 6 ft. 6 in. long, crosspieces 3 ft. 3 in. long, spreaders 9 in. by 1 in. and 2 ft. 9 in. long. (Plate **36,** Fig. 1.) 9 in. by 3 in. setts; uprights 5 ft. long, crosspieces 3 ft. 3 in. long, spreaders 2 ft. 9 in. long. (Plate **36,** Fig. 2.)

(*b*) Chambers.—Pitprops 4½ in. to 6 in. in diameter. Joists 5 in. by 2½ in. and 9 ft. long. Lagging 1½ in. to 2 in. boarding in various lengths.

2. *The small corrugated steel shelter.*—The dimensions are shown in Plate **37.** Three sections are shown, but more may be used to give a longer shelter.

To erect, lay out the 4 in. by 3 in. timber bearers, put the segments in position, drive in the clasp nails provided and nail on the 2-in. fillet.

If more head room than 3 ft. 8 in. is required the shelter can be raised on timber frames (Plate **38**). It should not be supported on a sandbag wall.

3. *The large corrugated steel shelter.*—An example showing the dimensions is given on Plate **39.** It consists of seven segments fastened together and erected in the same way as the small corrugated steel shelter.

The sheets of steel may be used singly, in which case wall plates must be provided. Care must be taken not to overload single sheets.

It will be noticed in the plate that a wedge-shaped or bevelled bearer is shown directly under the stringers. If there is any difficulty in obtaining or making these, a 2-in. flat plank can be substituted. It should be packed up with wedges for the full width of the 9-in. by 3-in. framing at each point where the plank crosses the framing. Another method is to notch a timber at a slant with the 9-in. by 3-in. framing.

4. *Curved corrugated iron* can be used resting on trench boards on edge, extra props being fixed every 3 ft. in the trench boards. This makes a quickly constructed trench shelter as shown on Plate **40.** It can also be used on timber frames, as shown on Plate **38,** Figs. 2 and 3. It is advisable to build up the framework on or near the site and to lift it bodily into position and then to place the roof in position.

5. *Troughing plates.*—These are flat, troughed steel plates usually 6 ft. or 9 ft. long and 3 ft. 3 in. wide.

They are considerably stronger than curved corrugated iron. It is advisable to have a central support.

6. *Timber frames.*—An example of a cut and cover dug-out with a composite roof of steel joists and trough plates carried on a timber frame is given on Plate **41.**

7. *Large span shelters.*—In splinter-proof shelters of larger dimensions than can be satisfactorily dealt with by the use of the standard steel shelters described above, it becomes necessary to carry roofs on girders, rails, heavy timbers, etc., which must be supported on framed uprights generally of timber. These frames have not only to carry the weight of the roof but have also to resist the side pressure of earth, the force of shell bursts and, in the case of gun emplacements, the shock of discharge.

Tables 51 and 52 (Appendix IV, pp. 390 and 391) give the safe loads that can be supported by various joists, rails, scantlings and poles.

For further information as to how to calculate the strength of joists, etc., *see* Chapter XVII.

20. Types

1. *Shrapnel-proof shelters* are dealt with in the Manual of Field Engineering, Vol. I. Some alternatives to the design given there are illustrated in Plates **37** to **41.** Splinter-proof artillery O.Ps. are shown on Plates **42** and **43.**

2. *Shell-proof protection.*—Reinforced concrete affords the most concentrated form of cover, plain earth the best.

As large quantities of concrete are difficult to obtain in the field it is usual, however, to employ instead an earth cover with a burster course of hard material near the surface. The function of the burster course is to explode the shell before it penetrates the earth cover. It must therefore extend well over the sides of the shelter.

Plate **41** shows a typical example of this form of mixed cover with some of the possible alternatives to the various courses.

3. *Heavy shell-proof protection.*—Against bombardment by shells of 8-in. calibre and over, the best protection is afforded by deep tunnelled dug-outs. The construction of these is dealt with in the following section.

21. Tunnelled dug-outs

1. The accommodation that may have to be provided includes :—

i. Command headquarters for company, battalion and higher fighting formations (Plates **44** and **45**).

ii. Accommodation for machine-gun personnel (Plate **46**).
iii. Accommodation for personnel working in observation posts.
iv. Living dug-outs for infantry and artillery.
v. Subways.
vi. Dressing stations (Plate **47**).

2. *Design.*—Two main types of dug-out are given, viz. :—

Type " A " (Plate **48**), Fig. 1 which is more suitable for men's quarters. This type involves less excavation for the accommodation provided and gives better ventilation.

Type " B " (Plate **48**, Fig. 2) which is suitable for headquarters, offices, etc.

3. *Entrances.*—

i. Every dug-out must have at least two entrances not less than 40 ft. apart. No attempt should be made to strengthen the head of an incline. No practical means will make it proof against a direct hit, and the use of concrete or girders only renders it more difficult to clear and repair.

The types illustrated on Plate **49**, Figs. 1 and 2, are designed to give the maximum amount of cover in the shortest space and to ensure that there is no break in the line of the elbow rest in the case of a fire trench.

The top of the first two setts should be sprinkled with earth or otherwise made to resemble the elbow rest or berm. This helps concealment, but the entrance must also be camouflaged with netting to destroy the dark shadow of the entrance.

In order to prevent entrances becoming sumps for the drainage of the trench a step is made 1 ft. above the bottom of the trench as illustrated.

ii. *Inclines.*—Inclines should be driven at a slope of 45° and should be close timbered with setts 3-in. thick for at least 15 ft. ; open timbering can then be used if soil is suitable, but setts must not be further apart than 4 ft. The minimum width admissible is 2 ft. 9 in., as in the standard sett. There are two methods of timbering, viz., vertical and normal.

iii. *Vertical timbering.*—Plate **49**, Fig. 2, shows the method of starting vertical timbering which can be carried on in the same way right down the incline if necessary in bad ground. It is more difficult than normal timbering (Fig. 1) and is not recommended where unskilled labour has to be used owing to the difficulty of cutting the steps. Legs shorter than 6 ft. give insufficient head room. Steps should have 9-in. tread and 9-in. rise. Vertical timbering is more suitable when rising to the surface.

iv. *Normal timbering.*—Plate **49**, Fig. 1, is stronger, requires shorter legs for the necessary head room and irregularity in width of the timber used does not affect the stairway as the steps are put in afterwards.

v. *Excavation and timbering.*—For either type first excavate the bottom and place the ground sill truly. Then put in the legs, excavating only enough ground to place them. Then excavate for and place the top sill. Dig out the remaining ground.

Never attempt to excavate for several setts to be timbered later ; this endangers the lives of those working, and, if the face of the side begins to " run " involves an immense amount of labour and leaves a weak entrance.

In working through bad ground with vertical timbering it may be necessary to use spiling, *see* para. 4, ii, below. The method of fixing the spiling is illustrated in Plate **49**, Fig. 3. After each sett is fixed the spiling can be removed and used for the next one.

Each sett should be " laced " back to the previous one, immediately it is put in, at top and bottom, by means of a short length of wood about 1 ft. 6 in. by 4 in. by 1 in. nailed on both sides. In the case of an incline timbered normal to the slope, the side pieces of the step form the bottom lacing.

Afterwards all setts should be strung together with 4 in. by 1 in. wooden runners, spiked about 6 in. from the top and bottom of each side or flat bar iron specially slotted.

Solid chalk is most easily broken to a " cut " (*i.e.* a narrow excavation, usually down one side). If timber is put in as above there is a cut, top, bottom and both sides. Picks should be systematically worked to break to one or other of these cuts and not used indiscriminately over the face.

For normal timbering a templet in the shape of a 45-deg. triangle with 2-ft. sides and a plummet should be provided.

Tool recesses should be provided at the bottom of each incline.

Plate **49**, Figs. 1 and 2, show the standard methods of breaking out from a fire trench (Fig. 2) and a communication trench, or bank (Fig. 1).

The five setts of vertical timbering in Fig. 1 are to give cover overhead as quickly as possible when it is intended to work with normal timbering for the remainder of the entrance.

Gas curtains are provided as shown, two at the top forming a lock and another at the bottom to prevent any gas reaching the galleries. The lock must be wide enough to admit a stretcher.

4. *Galleries.*—

i. In bad and doubtful ground, galleries should be cased, *i.e.* close timbered, but in ordinary chalk and dry clay they may be framed and sheeted, *i.e.* the setts may be spaced up to a maximum of 4 ft., thus economizing timber. Top lagging (1½ to 2-in. boarding) must always be used and, except in solid chalk, side lagging of 1 to 1½-in. boarding corrugated iron or expanded metal, etc., is also necessary.

ii. *Spiling.*—When there is any doubt as to the stability of the roof, work should be carried out by "spiling" (*i.e.* supporting the roof ahead of the excavation).

Plate **50** illustrates spiling. The whaling board, of 4 in. by 2 in. timber, rests on distance pieces placed on top of the top sill of the ordinary frame.

The distance pieces are large enough to allow the spiling boards (*i.e.* overhead lagging) to be hammered forward between the whaling board and top sill.

The spiling boards are maintained at the original angle by using a spare top sill as a distance piece, bearing on the spiling boards of the sett behind.

In very heavy ground spiling boards may bend with the weight before they can be driven home; in this case intermediate temporary setts are used. The forward sett supports the end of spiling boards, while the back one serves as a distance piece to maintain the angle of drive. The boards are driven from underneath the cap. This method necessitates the excavation of the ground between setts in two distinct operations; first, to place the intermediate sett and then to place the permanent sett. If it is necessary to pick out the ground ahead of the spiling boards to facilitate driving, only pick out enough to allow one board to be driven at a time.

Spiling boards should be at least 1 ft. longer than the span between setts.

iii. Excavation.—As for entrances, always break to a "cut."

5. *Chambers.*—

i. Pillars of solid ground of a minimum thickness of 12 ft. in chalk and 20 ft. in clay must always be left between chambers.

In ordinary soil, chambers should be excavated 9 ft. wide and timbered and the roof supported with standard R.S. joists on pit props. In clay or soft chalk the joists require intermediate props, which should be inserted afterwards. They need not be placed in the centre of a girder but should be arranged to facilitate bunking, etc.

Girders are normally spaced at 2-ft. centres in clay or sand, and at 2 ft. 6 in. to 3-ft. centres in chalk.

To prevent the side props from being pushed inwards they are connected to the girders by Z clips or brackets. The usual patterns are shown on Plate **36**, Figs. 4, 5, 6.

The clip shown in Plate **36**, Fig. 4, must be fixed when the girder has been put in place. Props should not be weakened by being notched.

Girders must be side-strutted to prevent them rolling over and buckling. Four struts of 4 in. by 3 in. timber are tightly wedged between one girder and the next, spaced at intervals of 3 ft. along the girder.

In clay, loam or sand, foot blocks 12 in. by 12 in., or in heavy ground, ground sills are necessary. In good chalk it is sufficient to let the prop 3 in. into the floor.

ii. *Excavation and timbering.*—Except in very solid ground, spiling should be employed (Plate **50**).

The excavation of the whole face in one piece should not be attempted.

Two methods are suggested below:—

No. 1 Method.—First drive a pilot gallery. The most economical size is about 5 ft. by 2 ft. This should be timbered and be approximately in centre line of the chamber. Such a gallery serves as a useful check on levels and direction.

In connecting between two entrances it is as well to push this right through and secure through ventilation prior to starting the chamber proper. Men work much faster in a well-ventilated gallery. Where speed is very important, however, the face of the chamber can be worked at when this gallery is 10 ft. in advance of it. The gallery then forms a "cut" to which the sides of the chamber are broken. Two men can work on each side.

No. 2 Method (without a pilot gallery).—Cut out the sides of the chamber 2 ft. 6 in. wide and the full height, driving forward the spiling boards over this area first. When both sides are removed to a sufficient depth to set the next props, cut out the top of the centre buttresses, driving spiling boards forward as before. Then catch up these boards by a beam underneath, supported on either side of the buttress by pit props. Set forward girder, distance pieces, whaling board and wedges and then pick out the centre buttress.

iii. *Breaking away chambers from galleries.*—This operation requires considerable forethought and care in execution, for not only will the height of the chamber generally be greater than that of the gallery, but it is also desirable that there should be a step up, from the gallery to the chamber, of from 4 in. in normal cases to 12 in. in very wet systems. The method for " A " or " B " type chambers is explained below.

FROM FRAMED AND SHEET GALLERIES

" A " type.—The method shown in Plate **51,** Fig. 4, in which a chamber 6 ft. 6 in. high (from floor to bottom flange of girders) is constructed off a framed and sheeted gallery 6 ft. 4 in. by 2 ft. 9 in. (internal dimensions), is a good one. It permits of the chamber being spiled straightaway from the side of the gallery, and of the standard gallery setts being used for the false-work, which is reduced to a minimum.

As will be seen from the drawing, the (standard) setts, off which it is intended to break away the chamber, are raised to a certain height above the normal level of the gallery. To start the chamber, the caps of the three raised setts, marked H, are temporarily propped, the legs removed, and a girder put in their place as shown. The chamber is then spiled straight off the side of the gallery as previously stated. When the excavation of the first bay is finished, the caps and remaining legs of the setts H are replaced by lagging and a girder supported on pit-props, the ground-sills removed, and the floor taken out to the correct level. This will be that of the gallery, and not of the chamber floor, if the gallery runs on farther; and in such cases any step up from gallery to chamber floor-level will be across the chamber instead of at the entrance to it, as shown in Plate **51,** Fig. 4.

The height by which the three setts must be raised must clearly be equal to the total of—

the difference in heights of gallery and chamber,
the height of the girder, less the thickness of spreader on the top-sill of the sett, and
the net height of step up into the chamber that may eventually be desired.

Thus in Plate **51,** Fig. 4, the chamber is to be 2 in. higher in the clear, the girder is 6 in. deep and the spreader 1 in., and an eventual 4-in. step is required.

So that the setts H must be placed $2 + (6 - 1) + 4 = 11$ in. higher than sett L.

" B " type.—It is only necessary to put in two frames at the higher level. Using temporary false-work, a short length of gallery is then broken out at right angles to one side (or to both sides if required by the lay-out). A cross gallery, 9 ft. long, is thus formed from the side of which the chamber is broken away. The cross gallery itself is finally timbered with pit-props and girders, as in method A, to form the first bay of the chamber.

FOR CASED GALLERIES

" A " type.—Plate **51,** Figs. 1, 2, 3.

1st phase.—The height of the gallery is raised 4 in. at a time until the height required for the chamber is reached (Figs. 1 and 2).

The last of these rising setts is a special sett with 3 in. by 3 in. sills and one 3 in. by 3 in. leg. The other leg is 9 in. by 3 in. and is fixed across the gallery (Fig. 1).

2nd phase.—12 long setts are placed at the full height (8 ft. 4 in. internal in Plate **51**) which gives room for the placing of two pit-props and a 6 in. by 3 in. R.S.J. required to commence the next phase (Fig. 1). On top of the R.S.J. chocks and a whaling board are fixed as shown. These now support the top sills of the 12 long setts mentioned above and the inside legs can be removed.

3rd phase.—Commence spiling and excavation for the chamber by one of the methods given in para. 11, above, and continue to required depth placing pit-props and R.S.Js. at intervals required by the nature of the soil (Fig. 3).

" B " type.—Plate **52,** Figs. 1, 2, 3.

1st phase.—As for " A " type except last or turning sett. This sett has to be of such a width that the pit props that come in the gallery do not obstruct the passage-way (Fig. 1). Both legs of this sett are 9 in. by 3 in. placed across the gallery and the sills are 3 in. by 3 in. as before.

The inside leg is cut 3 in. short and a temporary chock of 3 in. by 3 in., 9 in. long, is inserted to fill up the space so that the leg can be used for the cross top sill which is required in the third phase.

2nd phase.—Four setts of the increased width and height are placed in the gallery (Figs. 1 and 3). This gives room to turn inwards and drive a gallery to the width of the chamber as in phase 3.

3rd phase.—To start this gallery a sett is placed with its top sill supported one end on a leg and the other end on the leg of the turning sett mentioned in phase 1, removing the temporary chock. The top sill supports the ends of the top sills of the 4 long setts fixed in phase 2 and their inside legs can now be removed, thus exposing the face of the chamber.

Drive a gallery of setts 1 ft. less in length than the 4 setts of phase 2 if the step up to the chamber is to be 1 ft. and continue until the required width of chamber is reached.

4th phase.—Place the first pit props and R.S.J. (Figs. 2 and 3) and fix chocks and whaling boards to support top sills of gallery made in phase 3. Remove inside legs. Continue spiling forward and excavate chambers by one of methods mentioned in para. **5**, ii, above, placing pit props or R.S.Js. at intervals required by the nature of the soil.

It will be seen that work from a cased gallery is more complicated and is very difficult without special sizes of timber. It is therefore preferable, if the ground permits, to change to frames and sheeting just before the chamber is reached.

6. *Drainage.*—In wet ground, *i.e.*, where pumping is necessary, the water in the dug-out should be collected into one or more definite sumps. Correct levels are, therefore, of the greatest importance. The chambers should be up to 1 ft. higher than the gallery and should drain towards it. Galleries should have a fall of 1/50 towards the sump to counteract small errors in setting the frames.

Trench-boards should never be allowed in galleries. They collect filth and obstruct the drainage.

To ensure cleanliness, when the difficulties of transport are not too great, the floors of the chambers and galleries may be covered with a layer of fine concrete, 1-in. thick, laid on expanded metal which is nailed to the ground sills.

To prevent the roof of the dug-out leaking in shattered chalk, all shell holes above it should be filled in so as to develop a slight mound.

7. *Ventilation.*—Ventilation is best assured by adopting type "B" for men's quarters (Plate **48**, Fig. 2), and, in big systems, by siting the kitchens so as to assist ventilation.

From a ventilation point of view it is preferable, but seldom possible, to avoid having both entrances facing exactly the same way.

Vertical shafts, when used, should be utilized as kitchen flues and sited accordingly. In chalk, sound earth and clay, holes should be bored to the surface to take kitchen flues and to assist ventilation. Special precautions must be taken to prevent gas entering by the bore-holes.

If electricity is available the air in deep dug-outs can be exhausted by means of fans; alternatively, this can be achieved by means of a small stove of pillar or cylindrical pattern, placed at or near the bottom of the dug-out shaft. A length of stove pipe, connected to the base of the stove is led to the furthest end of the dug-out. After the fire has been lit and the stove door closed, the draught up the chimney of the stove will exhaust the air in the dug-out and fresh air from outside will take its place. If the outside air is contaminated by gas, some filtering arrangement, such as described in "Defence against Gas," should be installed.

8. *Lighting.*—Electricity is the most satisfactory source of illumination, but if it is not available candles or portable accumulator lamps should be used. Electric lamps are best placed in the corners of the roof and protected by roughly made expanded metal guards. Twenty-five watt lamps placed at 40-ft. intervals are adequate for subways.

9. *Bunking.*—A method for a 9-ft. chamber is shown on Plate **48** (*see also* Plate **44**), it provides a seat and a blank wall for hanging kit.

Bunks should be 6 ft. 6 in. by 2 ft. This governs the length of the chamber. The cubic air space available allows three tiers of bunks in chambers 8-ft. wide, but only two tiers in chambers 6 ft. wide.

10. *Gas curtains.*—Two curtains must be provided for each entrance, one near the head of the stairway, one 12 ft. lower down and, preferably, one at the bottom (*see* Plate **49**). Care must be taken that all signal wires, etc., pass through the frame, and are not carried around it, otherwise the curtains will not make a close fit. This especially applies to wires that are installed after the curtains are put up. Ventilation holes are best closed by a tapered wooden plug covered with blanketing. Manual of Field Engineering, Vol. I (All Arms), 1933, Plate 46, shows method of constructing the curtains.

11. *Disposal of soil and concealment.*—The concealment of the spoil evacuated is of the utmost importance. Shell-holes and old trenches can generally be utilized to a limited extent, but unless the amount of spoil to be dealt with is realized, and a

scheme of disposal is thought out beforehand and rigidly enforced, conspicuous heaps are certain to be formed. One method is to work the spoil into the parapets of dummy trenches in the vicinity.

Work at entrances should be concealed, and where no natural facilities exist (quarries, etc.), the spoil spread out and covered daily with surface soil. Constant supervision is necessary to prevent the site of the dug-out being disclosed.

12. *Protection against grenades thrown down the entrance.*—A wire netting screen placed a few feet down the incline prevents the grenade going down the incline or causes it to rebound into the trench. Bomb traps should also be constructed at the foot of all inclines. The bottom of these should be about 3 ft. below the level of the floor of the gallery.

13. *Working parties and footage.*—The usual working parties, exclusive of those employed in disposal of the spoil on the surface, are given below.

i. *Inclines.*

1 man picking.
1 man filling sandbags.
1 man carrying for each 10 ft. of entrance.

Progress for each shift of 8 hours should be about 2 ft. 6 in.

ii. *Galleries.*

1 man picking
1 man bagging } Reliefs for men at face.
1 man assisting

NOTE.—Two reliefs are necessary if a fair advance is expected.

Progress for each shift of 8 hours should be about 3 ft., and approximately 300 bags for each shift will be produced.

iii. *Carrying party.*—

1 man can carry 100 bags along 100 ft. of gallery for each 8-hour shift.

1 man can carry 100 bags up 10 ft. of entrance for each 8-hour shift.

The best method is to work in relays every 30 to 40 ft. of gallery and every 5 to 7 ft. of entrance.

iv. *Chambers.*—

(*a*) *No.* 1 *Method.*

1 man picking in pilot gallery.
1 man filling in pilot gallery.

Unless speed is of first importance, this gallery is driven in advance. Progress should be 4 ft. for each shift of 8 hours.

Provided that the pilot gallery has been or is being driven by men employed on chamber face :—

2 men picking.
4 men filling bags, setting and supporting timber.

These men provide reliefs for pick men.

Progress for each shift of 8 hours should be about 2 ft. 6 in., and approximately 560 bags will be produced.

Carrying party calculated as above.

(*b*) *No.* 2 *Method.*

2 men picking.
4 men filling and timbering, who relieve picking men as they tire.

Progress for each shift of 8 hours should be about 2 ft., and approximately 450 bags will be produced.

Carrying parties calculated as above.

Surface party :—The number of men dumping depends on nature of dumps and distance of carry.

One man can carry 100 bags 200 ft. in 8 hours on surface under ordinary trench conditions.

Labour underground can be economized by the use of trolleys and windlasses.

22. Buildings

1. The degree of protection against enemy projectiles afforded by buildings varies in accordance with the nature (*i.e.* brick, concrete, wood, etc.) and the part of the building concerned (rooms above ground, cellars, etc.).

2. Well-built brick buildings may, for the purposes of protection, be divided as follows :—

i. The rooms above ground give good shrapnel-proof protection, the rearward rooms being better than those nearer the enemy.

ii. The cellars give thorough protection against shrapnel, and when the walls and roofs which act as bursters are knocked down and the covering of the cellar is automatically increased, the cellars may be regarded as proof against light shells such as those from field guns.

3. The roofs of cellars should be shored up with stout pit props or frames sufficiently strong to support any protective layer (*see* Sec. **18**) that may be added, as well as the weight of any debris that accumulates from fallen walls, etc. All the cellars should be provided with two entrances and protected with gas curtains.

4. It may be decided to provide shell-proof accommodation from the first, which may take the form of 3 ft. to 5 ft. of reinforced concrete or the protection as shown on Plate **41**.

5. Another form of protection in buildings is to use steel shelters, which should be placed well back from the walls and covered with sandbags or concrete. The interval between the shelter and the wall should be left as an air space and not filled in with loose earth or rubble. Increased protection inside the building can also be obtained by building sandbag walls and providing a strutted roof which supports any fallen debris.

CHAPTER VI

AIR RAID PROTECTION

23. Engineer responsibility

Protection for personnel and material against attack by aircraft may be required in any part of the theatre of war. This chapter is primarily concerned with its provision in L. of C. and rear areas where tactical considerations do not govern the methods employed. In such areas means will have to be devised for protecting headquarters and other important centres, for sheltering labour and other personnel and for the safeguarding of installations, essential services and stores. It will fall to the engineers to advise on the measures to be adopted, on the selection and adaptation of existing structures as well as on the design and lay-out of new ones. In many cases they will be responsible too for the execution of the work. The principles that should guide them will be found in the succeeding sections of this chapter.

24. Nature of attack

1. Air attack may comprise bombardment with incendiary bombs, H.E., or gas. One or other of these forms may predominate according to the nature of the objective, but it is likely that the general practice will be to use all these together. This probable combination must always be borne in mind.

2. Details of bombs likely to be encountered and their destructive effects are largely a matter of conjecture. The summary in Table 2, p. 52, will, however, serve as a guide.

25. Protection required

Table 3, p. 53, shows types of construction and thicknesses of materials necessary to give adequate protection in various cases.

26. Shelters

1. To some extent the measures necessary for protection against the various forms of attack conflict. A shelter clear of buildings is the only one where the occupants can be safe from the effects of the incendiary bomb. Protection against splinters can usually be provided in a building, but this is not satisfactory against blast effect. In a trench protection from both splinters and blast is obtainable, but the gas concentration at the ground level is likely to be greater than it would be at some height above it. Once a trench or other underground shelter has been made gas proof, however, its chances of remaining so under heavy air bombardment are

TABLE 2.—DESTRUCTIVE EFFECT OF AIR BOMBS

Type (1)	Weight (2)	Penetration (3)	Destructive effect (4)
Incendiary.	2–60 lb.; the 2-lb. bomb seems the most likely for general use.	Light roofs (*e.g.* slates, tiles, C.G.I.), but probably stopped subsequently by even a light floor.	Bomb burns and will set alight any inflammable material.
H.E. i. With percussion cap.	Up to 3,000 lb.; 500 lb. probably the most usual, though 1,000 lb. possibly not infrequent.	Will burst on striking ground, though would penetrate one or two floors of an ordinary building before exploding.	More or less complete destruction of the building struck with widespread damage from blast and splinters to other structures within 100–150 yards and even farther off.
ii. With semi-armour piercing nose.		Will probably penetrate to cellar floor of the most substantial buildings before bursting.	
Gas.	Up to 250 lb. and even larger; also in form of spray.		Injury to personnel by direct contamination or through materials with which they come into contact.

TABLE 3.—PROTECTION AGAINST AIR BOMBS

Type (1)	Degree of protection afforded (2)	Types of construction and thickness of material necessary (3)
Incendiary up to 60 lb.	To resist penetration.	Reinforced concrete 5-in. thick or equivalent in alternative construction.
H.E. up to 3,000 lb.	Against a direct hit.	A shelter 35 to 40 ft. below ground or an equivalent built-up structure of reinforced concrete.
ditto.	Against splinters from a bomb bursting not nearer than 50 ft.	M.S. plate .... 2½ in. Road metal .... 6 ,, Concrete .... 12 ,, Brickwork .... 13½ ,, Gravel .... 16 ,, Sandbag wall .... 36 ,,
ditto.	Against blast effects of a bomb bursting not nearer than 30 ft.	Sandbag wall 3-ft. thick (average) with air space between it and the structure protected.
Gas.	Against penetration.	Sealing to make airtight.

greater than those of any above-ground structure. For this reason, therefore, shelters against air raids should, where possible, be below ground.

2. Full protection, *i.e.* against the direct hit of a heavy H.E. bomb, cannot of course always be provided. In many cases a lesser degree of protection will be all that is practicable. Shelters may be conveniently classified, therefore, according to the degree of protection each affords.

They fall into three groups :—

i. Splinter proofs.
ii. Gas and splinter proofs.
iii. Bomb proofs.

Each of these will be considered separately in the following paragraphs. There is one essential, however, which is common to every type of shelter—*it must be readily accessible to the persons for whom it is intended.* This is a point which must never be overlooked.

3. *Splinter proofs only.*—

i. Splinter-proof protection is obtainable in a variety of ways. Any of the materials and thicknesses enumerated in Sec. **25** will serve with a suitably strong roof, *see* Chapter V.

The walls of a well-built house afford good protection and cellars or ground-floor rooms may be used or a lean-to built against the outer wall.

ii. The dangers of fire and of the possibility of the collapse of the house over a shelter, however, will usually make it advisable to avoid buildings. In such cases simple trenches afford the best protection. They may be in the form of short lengths of slit trench or of longer lengths of traversed trench.

iii. In shelters such as these which make no provision against gas, respirators and possibly protective clothing as well will be necessary.

4. *Gas and splinter proofs.*—

i. An open trench is of course no protection against gas nor is it readily cleared of any gas that does penetrate. But a trench that is suitably roofed is not difficult to make gas-proof. Plate **53** gives examples of small shelters.

ii. Where large numbers have to be accommodated the shelters should be planned as a system, sited and organized with particular reference to the exits from the working places or habitations of the persons to be protected. Plate **54** shows a typical lay-out.

iii. The amount and type of lining to the trenches will be governed by the likely period for which the shelters will be required, the nature of the soil and the materials available. It will seldom be possible to leave the trenches entirely unrevetted and frequent inspection will be necessary to ensure attention to any points that would impair the gas-proofness of the shelters.

iv. Shelters such as those described in para. 3, above, can be made gas proof, but it will be difficult to keep them so where H.E. bombs are exploding in the vicinity, and there will of course be the dangers of fire and of the collapse of the building in or against which the shelter has been situated.

v. It is important that air-tight shelters are not over-crowded. The number of persons and the time for which these can safely be accommodated should be clearly indicated at entrances to the shelters. A formula for calculating these figures is given in para. 6, below.

5. *Bomb proofs.*—

i. Protection against the direct hit of a heavy H.E. bomb necessitates a shelter 35 to 40 ft. below ground level. In some places such shelters exist in the form of caves or old mine workings, but it will usually be a case of tunnelling dug-outs. To save excavation these will naturally be sited, where circumstances permit, in such situations as cuttings, hill-sides, etc., where the requisite overhead cover can be obtained quickly. But the advantages of thus economizing labour must never be allowed to overrule the much more important factor of accessibility as referred to in para. 2, above.

ii. The construction of tunnelled dug-outs and sub-ways is fully described in Chapter V.

iii. Where underground bomb-proofs are impracticable, reinforced concrete shelters above or just below ground level may have to be built. This form of construction should not, however, be adopted where the tunnelled dug-out is possible. The latter gives more certain protection, can be made with less labour and is much more easily altered, extended or repaired subsequently. The design of an overhead structure that can be relied upon to keep out the heavy H.E. bomb is a problem that has still to be definitely solved.

6. *Ventilation.*—

i. All underground shelters should, if possible, be provided with artificial ventilation. The number of people that can be accommodated in a shelter without ventilation is strictly limited and is dependent on the surface area available for the removal of heat and the condensation or absorption of moisture.

Under English summer conditions, shelters may safely be occupied for periods up to twelve hours if the surface area of the walls, floor and ceiling is equivalent to an allowance of 100 sq. ft. per person. For example, the following figures may be taken as a guide for typical rooms under any conditions in the British Isles :—

Size of room.	*Permissible No. of occupants.*
10 × 10 × 8 ft. ..	.. 5
15 × 10 × 8 ft. ..	.. 7
20 × 15 × 10 ft. ..	.. 13
30 × 15 × 12 ft. ..	.. 20
50 × 20 × 15 ft. ..	.. 41

ii. Under more crowded conditions, shelters must be provided with ventilation, which should be calculated on the following basis. For a period of occupation up to six hours in a shelter which allows 26 cu. ft. of air space and 3·5 sq. ft. of floor space per person, air should be supplied at a rate of 450 cu. ft. per person per hour.

The figures in the above paragraphs are based on the fact that in the circumstances described the increase in temperature and humidity of the air will produce intolerable conditions before any effects are felt as a result of increase in carbon dioxide or deficiency of oxygen.

In cases where other means exist for controlling the temperature and humidity (*e.g.* air-conditioning plant with cooling apparatus) it may be possible to reduce the quantity of air supplied.

The figures quoted in all cases refer to British climatic conditions. Under tropical conditions, the quantity of air to be supplied to ventilated shelters will have to be increased, and in the case of unventilated shelters the number of occupants will have to be reduced.

7. *Details and equipment of shelters.*—

i. *Entrances.*—Isolated dug-outs must have at least two entrances not less than 40 ft. apart. Systems of dug-outs should similarly have numerous entrances which should normally not be less than 5 ft. in width.

ii. *Partitioning.*—Except where protection against the direct hits of the H.E. bombs of the heaviest nature is absolutely assured, shelters should not be designed to hold more than some thirty persons each. Where a larger number has to be accommodated in any single chamber this should be broken up into compartments by sandbag walls 3-ft. thick or other structures to localize the effects of the burst.

Splinter-proof shelters such as those described in paras. 3 and 4, above, should not be constructed to hold more than twelve persons and in trench systems the intervening buttresses should never be less than 12 ft., and where possible should be 20 ft. or more.

iii. *Illumination.*—Large shelters and systems of shelters should have electric light installed. Where this cannot be done oil lamps will be found preferable to candles.

iv. *Bunking.*—In underground shelters it is advantageous to fit bunks. They facilitate control and lessen the tendency to collect in the passage trench (*see* Sec. **21**, 9).

v. *Equipment.*—Stores of tools and fire fighting apparatus should be provided at convenient spots so that occupants can at once deal with any damage to the shelter.

27. Protection of material

Apart from the provision of shelters for personnel it is to be expected that there will be a constant demand for the protection of installations such as power stations, pumping stations, telephone exchanges, etc., of dumps of material, and of distribution mains for water, gas and electricity. It will seldom be possible to give more than splinter-proof protection in any case. The general principle to be followed is to "compartment" the machinery or dump by splinter-proof dividing walls.

CHAPTER VII

CONCRETE AND REINFORCED CONCRETE

28. General

1. *Uses.*—Many opportunities for the use of concrete, both plain and reinforced, will occur in field engineering. Whilst in a war of movement its use may be mainly confined to the base and L. of C., in stabilized warfare there will be great scope for its employment in forward areas. Some of the chief uses to which it may be put are: piers, roads, walls, floors, beams, platforms, dug-outs, machine-gun emplacements, pill boxes, fencing posts, sleepers, retaining walls, storage tanks, etc.

2. *Types of concrete.*—

i. *Mass concrete* consists of a mixture in varying proportions of cement, sand and coarse aggregate such as gravel, broken brick or stone, and water.

It is used for foundations, retaining walls, etc., where the weight and bulk of the concrete give sufficient strength.

ii. *Reinforced concrete* is a combination of the above with steel bars. The steel is designed to relieve the concrete of tensile and shearing stresses against which it has small resistance. It is used where the bulk has to be kept to a minimum and strength is required, *e.g.* columns and beams, piles, roads, etc. It is important that the steel be placed exactly as designed or loss of strength will result.

29. Proportions in concrete

1. *Concrete may be proportioned in two ways :*—

i. The cement, sand and coarse aggregate are measured separately. The mix is specified as 1 : 2 : 4 or 1 : 2½ : 5, etc., meaning 1 cu. ft. cement, 2 cu. ft. sand, and 4 cu. ft. coarse aggregate, etc.

ii. The sand and coarse aggregate are obtained already mixed as ballast aggregate, and the cement and ballast aggregate are measured separately. The mix in this case is specified as 1 : 6 or 1 : 8, etc., meaning 1 cu. ft. of cement to 6 cu. ft. of ballast aggregate, etc.

2. *Water content.*—Only sufficient water is used to make a mix wet enough to work and place easily. Excessive water results in reduced strength.

The slump test affords a convenient method of testing the consistency of a mix on the site.

In important works the officer in charge may order periodical slump tests to be made.

The test is carried out as follows : A truncated cone-shaped mould, 12-in. high, 8-in. diam. at the base and 4-in. diam. at the top, is filled with the wet mix in layers of 4 in. at a time, each layer being punned thirty times with a ⅝-in. pointed metal rod. After the third layer has been punned, the mould is lifted off and the slump (*i.e.* the height through which the mix settles) is measured.

3. Table 4 shows suitable proportions of cement, aggregate and water for use in various circumstances presuming that the aggregate is dry. If the aggregate is wet the water should be reduced accordingly, the slump test being applied as a check if ordered.

TABLE 4.—PROPORTIONS OF CEMENT, AGGREGATE AND WATER

Class of work 1)	Portland cement. Cu. ft. (2)	Sand below ¼-in. diam. Cu. ft. (3)	Coarse gravel, broken brick or stone ¼ in. to 2½ in. diam. Cu. ft. (4)	Water. Gals. (5)	Slump. Ins. (Rough guide only) (6)
1. *Mass concrete.*					
For retaining walls. 1 : 6 bulk	1	2½	5	6	2
For foundations. 1 : 8 „	1	3	6	7½	2
For very rough work. 1 : 10 „	1	4	8	unimportant.	
2. *Reinforced concrete.*					
Thin vertical sections ...	1	2	3	5	6
Heavy sections	1	2½	4	5	2
Thin confined sections ...	1	1½	3	5	8
3. *Roads and pavements.*					
Lower course	1	2	4	5	4
Wearing course	1	1½	3	4½	4
Mortar for floor finish ...	1	3	–	5	2

For estimating the total quanity of water required allow about 20 to 27 gals. of water per cu. yd. of finished concrete.

30. Mixing and placing concrete

1. *Mixing.*—

i. *By hand.*—Two wooden platforms are required about 20-ft. square together with boxes for measuring the ingredients. (*See* Table 4, p. 58.)

Having decided what quantity can be dealt with, measure that quantity of aggregate and lay it on one platform in a flat heap about 9 in. high. On the other platform lay a proportionate quantity of sand, and over the sand a proportionate quantity of cement. Mix the sand and cement (dry) thoroughly by turning the heap over with a shovel. Shovel and mix sand and cement (dry) evenly over the aggregate and turn the whole over at least three times. Then add water gradually from a watering can in the proportion referred to in paras. 2 and 3 above, turning over the mixture with a shovel at the same time.

The water used should be clean. Salt water may be used if fresh water is not available, but it will make the concrete liable to absorb water.

ii. *By mechanical mixer.*—Better and quicker results can be obtained by the use of a mechanical mixer. The cement and sand and coarse aggregate are carefully measured before placing in the mixer. An accurate water measuring device should be attached to the mixer. The time of mixing should never be less than one minute for each batch, but the time may have to be increased with certain types of mixers.

The whole of the batch must be used before a fresh batch is taken from the mixer. No mixing of " set " concrete with newly mixed concrete should be allowed. Care should be taken that the mixer is cleaned out after each batch has been removed.

2. *Laying concrete.*—The mixed concrete should be placed in position as soon as possible and should be well, though not excessively, rammed. With a soft aggregate such as broken brick, heavy ramming tends to break the larger pieces and reduce the strength of the concrete. In no circumstances should concrete be disturbed after setting is commenced. Normal Portland cement takes an initial set in not less than thirty minutes and a final set in not more than ten hours. It will reach 60 per cent. of full strength in twenty-eight days. Rapid hardening cement reaches the same strength in about 6 days and is equal to normal cement one year old after twenty-eight days.

Quick-setting cement takes an initial set in not less than five minutes and a final set in not more than thirty minutes, reaching a similar strength in twelve hours. In either case the concrete must be incorporated in the work before the initial set has commenced.

Plain concrete should be carefully punned with wooden rammers in layers not exceeding 12-in. thick.

In *reinforced concrete* work, the concrete should be consolidated in layers 6 in. thick. The thickness of loose concrete before ramming in the vicinity of reinforcement bars is not to exceed 3 in. The concrete should be carefully rammed with steel rammers between and around the reinforcement to obtain proper contact between the concrete and the reinforcement.

Care must be taken that the reinforcement is kept in its right position during concreting. This can be ensured in the case of reinforcement near the bottom of a beam or slab by placing lengths of 1½-in. diameter piping under the reinforcement, drawing it along slightly in advance of the concreting.

Where work cannot be completed in one operation, it may be left off at the following points :—

i. *Walls.*—At the same level all round the structures.

ii. *Columns and piers.*—At the intersection of column or pier with the haunching of the floor beams.

iii. *Floors.*—Beams should be completed, but slabs may be finished half-way over a beam with a vertical face. Continuity bars should be left to link old to new work.

Newly laid concrete must be protected from frost, rain and hot sun. Directly it has taken its final set the surface is to be well wetted and kept damp for fourteen days in the case of normal Portland cement, and seven days with rapid hardening cement. This does not prevent the surface being put into use, if necessary, before these times. Frost has little effect on rapid hardening or quick setting cement concretes.

Concrete is best kept moist by covering it with wet sand or sacking, or even by ponding it with water.

Clean barrows, preferably iron, should be used, and wheel runs provided to site of depositing.

In making horizontal beams, concreting should be carried out in sections, starting from one end, and not in thin layers along the whole length of the box.

Newly mixed concrete when dropped from a height tends to separate, the larger stones falling to the bottom. No concrete should, therefore, be deposited with a drop exceeding 4 ft. ; the mix must be carefully lowered into place.

3. *Laying concrete under water.*—Good concrete can be laid under water, but care must be taken to prevent the cement from being washed out of the mixture. There are several methods of effecting this :—

i. The concrete may be placed in loosely woven sacks or paper bags, the former being preferable. This is the best method for use in running water.

ii. The concrete may be passed through a pipe called a tremil reaching from the surface of the water to just above the work.

iii. The concrete may be lowered in bottom-opening skips, the top surface being protected by tarpaulins.

A fairly dry mixture should be used for work under water ; tamping should be avoided.

4. *Jointing and bonding.*—If work cannot be completed in one operation, the top surface must be left rough. To ensure a bond between the new and old work, a few small " plums " or stones should be dropped on the top surface.

Before adding new concrete, the surface of the old concrete should be well scraped and cleaned to remove grease and dirt and the surface film that may be formed. If the old concrete has partially hardened (*i.e.* is more than four hours old with Portland cement), a ½-in. layer of cement mortar similar to that in the new concrete (*i.e.* the new concrete mix minus its coarse aggregate) should be first laid, and the new concrete laid at once.

If the concrete has set for more than three days, the old surface should be chipped over with a sharp pick, then wire brushed and coated with pure cement slurry before laying the ½-in. mortar layer.

5. *Reinforcement.*—Dimensioned drawings of reinforcement should always be provided and must be accurately followed.

The following practical points are important :—

i. Splices on rods should be lapped for a length of 40 diameters.

ii. Fabric should be lapped not less than 15 in. at the ends and 3 in. at the sides.

iii. Steel must be clear and free from scale before fixing.

iv. Ends of bars should be hooked (*see* Fig. 1).

v. Cross rods must be tied to longitudinal rods with soft iron wire.

vi. The cover required over bars in slabs and walls should be not less than ½ in. or the diameter of the bars. In beams and columns the minimum cover should be 1 in.

vii. The space between bars should not be less than 1½ times the size of the longest aggregate and not less than 1¼ times the diameter of the bars. Bar spacers or blocks of concrete are necessary to keep the bars in their correct positions and to ensure the specified cover.

viii. Accuracy in bending is essential. Where possible the steel work should be assembled on the bench and transferred as units to the forms. Bars should be bent cold when possible.

6. *Shuttering and centering.*—Concrete work cannot ordinarily be constructed without shuttering or centering to support it until it has set.

For shuttering, partially seasoned timber is best and preferably dressed on all four sides. The usual sizes of timber employed for formwork are as follows :—

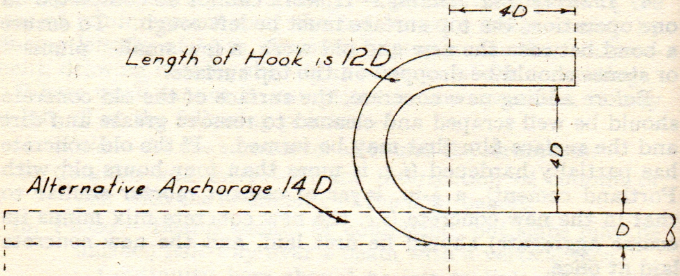


FIG. 1.—REINFORCEMENT BARS—END ANCHORAGE

Slabs	1 in.
Wall sheeting	1 in. to 1½ in.
Column sides	1 in. to 2 in.
Joists	4 in. by 2 in. to 6 in. by 3 in.
Studs	4 in. by 2 in. to 6 in. by 3 in.
Beam-bottoms	2 in.
Posts	4 in. by 4 in.
Cleats	4 in. by 1 in.

Plates **55, 56** give typical designs of formwork.

Shuttering should be designed to prevent :—

i. Distortion or collapse due to pressure of the concrete.
ii. Escape of mortar.
iii. Damage to itself on removal.

In order to prevent timber used for shuttering from adhering to the concrete, it must be covered with grease, oil, soap or whitewash before the concrete is laid. After being dismantled, it must be thoroughly scraped before being used again. Shuttering and centering may be removed after the periods stated in Table 5.

TABLE 5.—REMOVAL TIMES OF CENTERING

Nature of work (1)	Normal Portland (2)	Rapid hardening (3)	Quick setting (4)
Columns, one side only	4 days	1 day	12 hours
Columns, remaining 3 sides ...	10 ,,	2 days	12 ,,
Beams, sides	4 ,,	1 day	12 ,,
Beams, bottoms	28 ,,	6 days	24 ,,
Walls, 6 in. thick and under ...	5 ,,	1 day	12 ,,
Walls, over 6 in. thick	10 ,,	2 days	12 ,,
Floor or other slabs	14 ,,	2 days	24 ,,
Blocks cast in wooden moulds—			
Sides	12 hours	12 hours	—
Bases	36 ,,	24 ,,	—

During bad weather these periods should be increased.

TABLE 6.—MATERIALS FOR ONE CUBIC YARD OF FINISHED CONCRETE

Based on loose cement weighing 90 lb. a cu. ft. and a cu. ft. of loose, moist, coarse sand weighing 89 lb. when dry. The coarse aggregate is of an average type with 45 per cent. voids.

Mix (1)	Cement (lb.) (2)	Sand (Cu. ft.) (3)	Coarse aggregate (Cu. ft.) (4)
1 : 1½ : 3	697	12	23
1 : 2 : 3	633	14	21
1 : 2 : 4	548	12	24
1 : 2½ : 4	510	14	23
1 : 2½ : 5	450	12	25
1 : 3 : 6	383	13	25
1 : 4 : 8	294	13	26
Bulk mixes :—			
1 : 6	382	25	
1 : 8	297	26	
1 : 10	243	27	

Table 7.—Dimensions of Measuring Boxes

Size of box	Capacity
12 in. × 12 in. × 12 in.	1 cu. ft.
15 in. × 15 in. × 11½ in.	1½ cu. ft.
15 in. × 15 in. × 15⅜ in.	2 cu. ft.
18 in. × 18 in. × 13⅜ in.	2½ cu. ft.
18 in. × 18 in. × 16 in.	3 cu. ft.
18 in. × 18 in. × 21⅓ in.	4 cu. ft.
18 in. × 18 in. × 26⅔ in.	5 cu. ft.
24 in. × 24 in. × 18 in.	6 cu. ft.
24 in. × 24 in. × 24 in.	8 cu. ft.
30 in. × 30 in. × 26 in.	½ cu. yard.
36 in. × 36 in. × 36 in.	1 cu. yard.

31. Concrete shell-proofs

1. In the construction of shell-proof dug-outs, machine-gun positions, O.Ps., etc., concrete is of the greatest assistance. It must, however, be remembered that in the case of O.Ps. and machine-gun positions concealment is of primary importance as, however proof the structure may be against shell fire, it may be impossible to use it if it is frequently struck by shell fire.

The concealment of concrete structures is difficult, and therefore full protection may in some cases have to be sacrificed and medium shell-proof cover accepted.

Full protection is the first consideration in the case of dug-outs for garrisons.

The work involved in constructing concrete dug-outs is so great in proportion to the accommodation provided that they should not be attempted in any number unless the transport of stores to the site by tramway or road is feasible. The employment of carrying parties for concrete work is usually too slow and laborious a method.

2. Mass concrete has more resistance to shell fire than brickwork, but reinforced concrete, if properly designed and constructed, is better than either and should always be used in permanent work.

3. The resistance of concrete depends largely on its being monolithic, but concrete blocks if properly bonded with steel rods well grouted in will afford good protection. To obtain a degree of strength equal to monolithic concrete great care must be exercised in construction.

Except in stabilized warfare when factories for the making of blocks on a large scale might be started, concrete blocks will not be a practical proposition. With rapid hardening cement, which hardens in two to three days, there is little advantage to be obtained from this form of construction, except standardization of design and absence of formwork at the site, which would permit of the use of less skilled labour.

4. Thickness of reinforced concrete required :—

Table 8.—Protection against Shell Fire

Size of shell to be resisted (1)	Thickness of Walls and roof (2)	Thickness of Floor (3)
6-in. (150 mm.)	3 ft. 6 in.	1 ft.
12-in. (300 mm.)	5 ft. 0 in.	1 ft.

5. For details of concealment, burster courses, etc., *see* Chapter VI.

6. The conditions under which work has to be carried out, *e.g.* by night, under camouflage by day, lack of skilled labour, etc., render the adoption of the best practice difficult, but, provided the following general rules are followed, the reinforcement will not be wasted.

7. *General rules for construction of reinforced concrete shell proof.*—

i. The ideal section is that of a box in which the solid structure bears a high proportion to the interior.

ii. Reinforcement is required :—

(*a*) On the inner surface and parallel to the surface of roofs, walls and floor respectively, to resist tensile stresses in the concrete, localize fractures and distribute the shock, so preventing large pieces becoming detached and injuring the occupants.

(*b*) On the outer surface to resist penetration of the shell and to distribute the stresses due to impact.

(*c*) To bind (*a*) and (*b*) together to resist shear and consequent lamination.

iii. The most suitable reinforcement for this purpose is :—

(*a*) A grid of ½-in., ⅜-in or up to 1¼-in. steel bars arranged to form squares of 6-in. to 10-in.

sides, wired together at crossing places, and placed about 3 in. from the inner surface.

(*b*) A similar grid placed within 6 in. of the outer surface.

(*c*) ¼-in. to ⅝-in. diam. stirrups binding the inner and outer reinforcements together and spaced at not greater than 9-in. intervals.

Large mesh expanded metal or other mesh reinforcement such as B.R.C. fabric No. 3 can be used instead of bars for the grids and is equally effective.

iv. Floors should be reinforced with a layer of XPM or fabric near the upper surface.

v. Doorways and other openings should have reinforcement round them connected to the roof, wall and floor reinforcement, the lintel being reinforced to support the roof, and the joists reinforced for the full thickness of the wall to support the thrust of the side walls when struck by a shell.

vi. For all dug-out work a strong quick setting concrete is required in the proportion of 1 : 2 : 4. The aggregate used round the reinforcement should be made of ½-in. to ¾-in. gauge.

vii. An alternative method of construction, by making use of steel troughs, is the usual practice in the case of protection required against 8-in. or heavier type shells. The mass of concrete reinforced as described above, rests on the steel troughing, but the lower ends of the stirrups are bolted into the troughs.

8. *Typical designs* are shown as follows :—

i. Concrete machine-gun shelter. Plate **24**.

ii. Concrete shelter for forty men in ruined building (Plate **57**).

iii. Concrete machine-gun emplacement with medium cover (Plate **58**).

CHAPTER VIII

CONCEALMENT

32. Introductory

1. The general principles of concealment are dealt with in the Manual of Field Engineering, Vol. I (All Arms), 1933, Chapter VI. Concealment, especially in position warfare, will often necessitate the use of skilled labour and in this volume the subject is elaborated in more detail for the benefit of the engineer.

2. The aim of concealment is to frustrate two classes of observation :—

i. *Visual observation*, either from the ground or low-flying aircraft.

ii. *Photography* from the air and observation from the high-flying air observer.

33. Visual observation

1. The following points assist concealment from the visual observer :—

i. Colour or tone.

ii. Breaking up the outline.

iii. Avoidance of well-defined shadows, particularly if there is a series of similar objects in line.

2. *Colour.*—

i. By using natural substances, turves, etc.

ii. Painting, which may be either " disruptive " (*i.e.* to prevent a visible object being recognized), or " realistic " (*i.e.* to make an object look like something else).

(*a*) *Disruptive painting.*—Masses of contrasted colour break up the outline and contradict the shape of the object, or its shadow. This method of concealment is used for objects in motion and not in proximity to a solid background. The underside should be painted light (to minimize the depth of a shadow), and the upper side dark (so as to contradict the natural direction of the shadow).

Moving objects should be treated to contradict their shape as, in nature, movement is always conspicuous.

Boldness of design and strong contrasts in colour are important; the patterns should therefore be on a large scale. Three masses of colour are generally sufficient. (*See* Sec. **35**.)

(*b*) *Realistic painting*, or deliberate imitation, is used when an object is fixed and close to a solid background.

For effective concealment, the following points require attention :—

i. The outline of the object must be broken up.
ii. The edge of the object must not stand in relief against the background.
iii. Shadows on the object should be toned to those on the background. The appearance of these is affected by the position of the enemy and of the sun (*see* Sec. **34** (3)).

Notes on colours, brushes, and paint formulae are given in Sec. **35**.

(*c*) *Breaking up the outline*.—This purpose is best served by siting amongst natural cover. If an expert artist is available, screens, painted to imitate that cover, may be used. Non-expert painting will not tone in with the natural shadows.

(*d*) *Avoidance of well-defined shadows*.—This is more important against air observation than against ground observation. When considering the low-flying aeroplane, shadows will not be of paramount importance unless they have a very distinct shape or their grouping attracts attention.

34. Photography

1. The great improvements effected in the construction of cameras, lenses and plates make photography by far the most reliable medium for recording air observation. Stereoscopic photography, which enables objects to be viewed in relief, and the infra-red plate, which alters the tone value of colours, make concealment from the air still more difficult and the subject is in consequence likely to undergo change in technique.

2. *How objects photograph*.—A photograph records in various tones of black and white. The various colours and textures of nature are interpreted in the photograph by tones of different

values. Texture plays the most important part in determining tone. Colour is a secondary consideration, but care must be taken that, in attempting to deceive the camera by the use of tone, an object is not made conspicuous to an observer by neglect of colour.

A smooth white surface will photograph white, but a rough or textured white surface will be recorded in a lower tone owing to the innumerable small shadows cast. Similarly, a smooth black surface will be a lighter tone than a textured black surface which will photograph black.

Plate **59** illustrates tone values of various surfaces found in a landscape. Plate **60** illustrates the tone values of various colours.

3. *The aim in designing concealment against the camera* or high observer is to make the object to be concealed photograph in the same tone as the surroundings. The position should be carefully photographed if possible during construction, when completed and, occasionally afterwards to see if it may be disclosed by anything.

4. *The following points require consideration* :—

i. Concealment of cast shadows.
ii. Concealment of the object itself. The tone value of the material used must be similar to a natural object.
iii. General aspect, taking into account :—
    (*a*) Tracks.
    (*b*) Similar objects placed near together that may attract attention. The point here is to avoid any form of symmetry. Four guns, in a battery, attract far less attention if staggered than in line.
    (*c*) How much the position is likely to be given away (for example, the sound, flash and blast mark of a gun in action).

5. *Concealment of cast shadows*.—

i. *Shadow covering*.—Sloping material of the right texture should be placed from the edge of the object casting the shadow to the ground level at such an angle that the light will be reflected. This angle is never greater than 30 degrees. Photographs are generally taken in the morning and in the evening when the sun is low, therefore the angle must be small on the east and west sides.
ii. *Elimination of shadow*.—This is done by erecting over the object a cover composed of netting of various mesh, or wire netting, *see* Sec. **36**.

iii. *Shadow distortion.*—This is affected by erecting silhouettes. Silhouettes may either be made to distort the shadow, in which case the observer will know the object is there without being able to identify it, or they may be made to cast another shadow elsewhere, similar to that of the object to deceive the observer.

6. *Concealment of the object itself.*—This can be done in two ways :—

i. Blending with the background.
ii. Simulation of some other object.

Blending depends on a study of tone values and colour alone cannot be used for blending or simulation.

7. *General aspect.*—During a period of position warfare, works tend to become standardized in design. It will probably be possible, by carefully comparing different photographs, to prepare an interpretation key which will facilitate the detection of new works. It is clear, therefore, that after an advance a large measure of concealment is given by ingenuity in variation of trace and construction of work, irrespective of its visibility.

Each case of concealment will require separate treatment and for any area the concealment of each object must be considered in relation to the general scheme of concealment in the area.

It is easier to deceive the eye as to the nature of an object than to hide the object completely. The general scheme of concealment may include the use of dummies so placed as to distract attention from the objects to be concealed, while the latter are made as inconspicuous as possible. Examples of rendering objects inconspicuous, which will be co-ordinated in a general scheme, are :—

i. Siting so as to avoid regular patterns or straight lines.
ii. Continuing a track (which would otherwise draw attention to an object) to some point beyond it, and, if possible, to a dummy.

The question of tracks is of primary importance. It is no exaggeration to say that 90 per cent. of the features discovered on photographs have attention first drawn to them by tracks. The existence of tracks will render abortive the most skilful artificial concealment. For this reason siting, as a preliminary to concealment, is of vital importance.

Whenever cover has been erected it should be remembered that the tendency of troops is to walk round the edge of it, thus forming a track. Some small obstacle (*e.g.*, like a croquet hoop) should be put out to discourage this.

iii. In all cases where covers are used it is of paramount importance that they should be erected before any work is begun.
iv. Removal of spoil to a distance.

35. Materials

1. *General.*—A thorough knowledge of the materials used in concealment is essential in order that each article may be used in the right place and in the most economical way. If the wrong material is used the scheme is doomed to failure, as bad concealment advertises itself.

Artificial concealment should not be employed unless the surroundings demand it. In many cases a better result is obtained by intelligent siting and skilful use of natural material.

Materials may be broadly classed under two headings :—

i. Artificial (*see* Table 9, p. 72).
ii. Natural (*see* para. 3, below).

2. *Paints and colours.*—

i. *Brushes.*—Economy in the matter of brushes is important. They are easily ruined by being left uncleaned after use. If there is no time to clean them, stand them in a bucket of water. This will prevent them getting dry and becoming useless for the next day's work.

ii. *Paint formulae.*—In the following table the numbers show the proportions *by weight* in which the dry pigments should be mixed before adding to an equal weight of the medium.

The medium is known as " mocha," and, as its composition shows, is a distemper :—

Water	1 gal.
Size	1 lb.
Boiled oil	½ pint.

These are boiled together and the pigments then added. This should be done the day before use.

To imitate :—	Use :—
Grass and other green foliage.	Brunswick green 6. Yellow ochre 5·5.
Red sand and gravel.	Yellow ochre 6. Venetian red 0·016.
Loam.	Whitening 3. Yellow ochre 3. Vegetable black 0·2.

TABLE 9.—ARTIFICIAL MATERIALS USED FOR CONCEALMENT

Material (1)	Appearance (2)	Examples of use (3)	Remarks (4)
i. Canvas hessian.	Smooth, close woven, photographs light.	Imitation of woods, tracks, newly-turned earth. As a cover in grass country. Imitation of living foliage. Imitation of water in shell holes.	When cut into 12 in. by 2 in. strips and woven into a wire or fish netting foundation. Attached to dead trees, etc. When painted with oil paint.
ii. Canvas scrim—30 ft. long, 6 ft. or 12 ft. wide.	Loose woven. Photographs medium dark.	Imitation of shell torn ground. Reducing reflection at night from large buildings. As a cover for trenches, dumps, etc.	Large irregular patches attached to wire or fish netting. *E.g.* hangars.
iii. Coir netting.	Photographs very dark when painted.		The best colouring matter is black distemper.
iv. Wire gauze.	When painted, appears very dark.	Covering apertures Realistic painting.	*E.g.* loopholes, O.Ps.
v. Wire 30 ft. by 12 ft. or fish netting 30 ft. by 30 ft.		Foundations for covers.	Best mesh is 1½ in. to 2 in. Fish netting inflammable.
vi. Expanded metal.	*See* Sec. 34, 2.	Concealing blast marks.	No painting required.
vii. American cloth.	Use red variety.	Imitating dirty water.	
viii. Paint or colouring matter.		General use.	Distemper most useful.
ix. Plaster. Papier mâché. Cement.		Portable loopholes, O.Ps., sniper's heads, concrete M.G. emplacement covers.	
x. Mastic.		As for ix. Toning of roofs and walls.	
xi. Tar.		With hay added, produces a deep tone.	Only useful on smooth surfaces.
xii. Gas piping. Wooden posts. Conduit.		Frames for covers.	

For painting on metal, good results can be obtained by the use of ordinary oil paints mixed with fine material, such as sand, to give a matt surface.

3. *Natural materials and their uses.*—

i. The importance of making the maximum use of natural materials cannot be too strongly emphasized. Artificial materials are not always obtainable, and they cost money and absorb transport which might be more profitably employed elsewhere. Natural materials should not be collected from an area too close to the selected site. In the Great War a certain work was most cleverly concealed, but the turves employed were cut in an area only some 200 to 300 yards distant. Suspicion was at once aroused and, aided by tracks, a minute survey of the surrounding ground resulted in a discovery of the work in question.

ii. *Hay and grass* is used by threading or knotting it into netting. Netting threaded with grass is useful for covering trenches, saps, etc., but frequent renewal is necessary as grass soon dies.

When netting is used to eliminate shadows, hay and grass may be knotted to it to form projections which catch light and so break up the shadow.

iii. *Bamboo* is used in construction of frames for carrying covers.

iv. *Branches and foliage* are useful for covering the litter around gun emplacements.

v. *Broken turf* creates shadows in the sunlight, but on a grey day and in flat lighting, as at mid-day, the contrast lessens.

vi. *Sub-soil* is different in tone from surface soil, and in all work of concealment, care should be taken to preserve the top soil and replace it on top when the digging is finished.

The construction of mines or deep dug-outs has frequently been established from the presence of chalk spoil in shell-holes, when it is known that chalk does not exist near the surface.

36. Covers

1. Covers are composed of netting of varied mesh, the mesh being small at the centre and increasing irregularly in size to the irregular edges. Alternatively strips of dyed fabric or scrim are tied to the cover ; there should be more of these strips in the centre than at the edges of the cover.

The centre piece must be thick enough to hide the shadow of the object itself whilst its own shadow is hidden by the outer portion, the shadow being thus graded to nothing.

2. *Points to be observed in designing covers.*—

i. The long shadows of morning and evening are exaggerated by a cover that stands high off the ground. Keep as low as possible.

ii. It is most important that the top of the cover should be absolutely flat but it is essential for the flat top to assimilate in tone the surrounding features. If the cover sags a shadow will be cast on its top which will show plainly in a photograph.

iii. *Colour.*—If a net, etc., is too green for its surroundings the addition of dead grass will alter the tone. If the surroundings are bare earth and the only concealment available is green, mud may be applied to it.

Scrim painted one colour only should *never* be used by itself in the open; for such use it must be specially painted.

iv. *Opacity.*—The knots of grass, etc., attached to concealment nets are not sufficiently dense to hide light-coloured objects such as sandbags, trench boards, spoil, etc. Coloured scrim or anything that will darken the tone should be spread over such objects. Any bright portion of the object that may reflect light through the netting must be dulled, if possible, or the cover must be thickened in the centre. For example, in a typical battery position in grass country, the netting should be erected horizontally over the emplacement and, in addition, the spoil should be covered with coloured scrim or, if that is lacking, brushwood. The colour of the scrim or brushwood is of no importance in such a case, provided it is dark enough to prevent the light-toned spoil showing through the concealment above.

Another case that may often arise is that of a whole battery under a continuous cover of fish nets. Each fish net has thinned edges, but the requirements of the position are that the whole centre of the cover should be opaque, and all the edges (front, back and sides) thinned. To achieve this it will either be necessary to make the inner nets overlap, or else to supplement the thickness of their edges.

v. *Irregularity of pattern.*—The shadow thrown by erected cover can be easily judged by looking at its outline on the ground when the sun is low.

The rolls of wire netting issued have no thinned edges, as it is impossible to predict at the factory which particular roll will occupy an outer position. The thinning, when necessary, should be done *in situ*, and with reference always to the shadow cast.

It is seldom waste of material to employ it for increasing the area of a cover with a view to producing irregularity of outline.

vi. *Materials.*—Table 10 shows the best materials to use for various types of country.

TABLE 10.—MATERIALS FOR COVER IN VARIOUS TYPES OF COUNTRY.

Nature of country (1)	Material on cover (2)
Grass country ...	Strips of green canvas or raffia knotted on foundation.
Grass and earth ...	Large, irregular islands of scrim painted earth colour, surrounded by green canvas knots.
Shelled areas ...	Large, irregular islands of scrim mud colour in centre. Smaller patches at edges.
Mining districts ...	Black and white alternating canvas strips, preponderance of black.
Ruins	Red, white and brown strips.
Gorse and heather ...	Darkened coir (coir rope) nets on irregular framework.

3. *Erection and maintenance.*—As a general rule, wire netting concealment is preferable to fish netting in the normal conditions of trench warfare, because it is stronger and more durable. Once erected, it requires less constant attention. Its chief disadvantage is its bulk as compared with an equivalent area of fish net.

It is impossible to lay down any standard type of erection: every position has its individual peculiarities.

A concealment, to be effective, requires constant attention or the materials themselves will deteriorate. The addition of local material will frequently enable seasonal changes to be made.

4. *Types of cover.*—There are two types of cover in general use.

i. The *over-all cover*, composed of fish netting or other suitable material with a flat and irregular top and sides extending well beyond the work in every direction to protect it from oblique view. This is designed against all types of observation but it is not so good against air photography as noted in the following sub-paragraph.

ii. The *wire-netting cover* which is merely a flat and irregularly outlined cover of wire netting of varied mesh. It is designed mainly against photographic reconnaissance and is semi-transparent when viewed optically at low altitudes.

The chief advantages of the wire netting cover over the over-all cover are :—

(*a*) Reliability against air stereoscopic photography up to the present. The flat over-all can be invariably detected by this means.

(*b*) It is non-inflammable.

(*c*) It is durable.

(*d*) It is comparatively easy to manufacture.

(*e*) It requires a smaller area.

Disadvantages.—

(*f*) Present lack of an easily portable form.

(*g*) Difficulty in handling large areas of wire netting.

5. *Over-all cover.*—All the points enumerated in Sec. **34**, must be observed. In addition the cover must be provided with a flap (in the case of guns) to be raised while firing.

For size, 12 ft. between adjacent poles and a height of 6 ft. is the maximum advisable, beyond this height the structure tends to become unwieldy and susceptible to damage in a wind.

6. *Wire-netting cover* (*see* Plate **61**).—This cover is made with a centre of ⅜-in. mesh netting surrounded by a fringe of ½-in. netting. A second layer of ⅜-in. netting is superimposed immediately over the object to be concealed and the cover is then painted as explained below.

It is essential that the object to be concealed should present a matt surface to the light, otherwise it will be distinguished through the cover, the extent of which is determined by the length of the cast shadow. This type, if properly handled, should throw a shadow of negligible quantity, but if the netting be allowed to sag and thus present an opaque surface to the sun's rays, this advantage will immediately be nullified.

A very dark non-reflecting background such as a spoil bank in a coal mining district would be most unsuitable for the employment of this cover, which depends upon reflected light for its opacity.

The degree of efficiency of the cover may be said to depend on the reflective properties of the wire mesh. Actually an all white cover is more opaque than a green one ; a black-painted netting is valueless as it is transparent.

Although the transparency of the cover, when viewed from beneath, gives little sense of security, it must be remembered that this type of screen does not depend upon mass, but on an infinite number of minute curved surfaces reflecting light in every direction. It is an elaboration of the old-fashioned bead blind, where those inside had an undisturbed view from the windows thus equipped, knowing that they were invisible to the passer-by in the street.

7. *Mound-shaped type of cover.*—Unless an existing mound is being removed and replaced by concealment, care should always be taken to give an irregular outline to this type of cover.

The erection of this type involves less trouble and material than with the flat topped type, but the results are not always so satisfactory, as access and free movement are restricted. It is also very liable to detection owing to its shadow, unless sited in particularly favourable surroundings.

37. Screens

1. As they require time and material to erect, the use of screens is usually confined to stabilized or semi-stabilized warfare. There are, however, occasions under mobile conditions when an opportunity occurs for using screens rapidly made out of local materials.

2. The primary aim of screening is concealment from view in order to permit free and unobserved circulation of traffic.

Screens are also employed for the purpose of concealing from observation :—

i. Battery positions and gun flanks.

ii. Work in progress.

They are also used for :—

iii. Thickening hedges that are not sufficiently thick in themselves.

iv. Encouraging the enemy to waste ammunition by their erection where there is nothing to hide or conceal.

3. Screening may be carried out by means of :—

i. Artificial screens.

ii. Natural screens.

4. *Artificial screens* are made of :—

i. Wire-netting woven with grass, brushwood, or canvas strips (Plate **62**, Figs. 1 and 2).

ii. Brushwood and tree branches interwoven on horizontal wires stretched tightly between two uprights.

iii. Canvas, or coir, suspended on strongly braced poles.

Of these, canvas and coir require more maintenance as they do not stand the weather well.

5. *Natural screens* are made by supplementing the height or thickness of existing hedges, copses or fringe of trees to render them more effective without making the fact that they are screens conspicuous.

A screen should be sufficiently opaque to hide movement from any but very close and continuous scrutiny. The efficiency of any screen, except one absolutely opaque, is influenced by the background. A comparatively transparent screen may be successfully used in combination with a background of hedges and trees, or if it is set obliquely to the enemy's angle of view.

In order to hide movement at ranges between 2,000 and 4,000 yards three-quarters of the surface of the screen should be opaque. Screens may be either plain or camouflaged.

6. *Road screens.*—Roads running perpendicular to the front line are best screened by hanging across the road vertical screens between trees, houses or poles (Plate **63,** Fig. 1).

For roads running parallel to the front, short lengths of about 30 yards, placed in echelon, and overlapping each other, are better than long continuous lengths. This method permits of plenty of passage ways, and limits damage by shell fire (Plate **63,** Fig. 2).

Roads running obliquely to the front can be concealed by screens facing the front, arranged in echelon (Plate **63,** Fig. 3).

7. *Flash screens.*—Screens have been used successfully to hide gun flashes at night from the front and from a flank.

In one case where the flashes of a battery were visible from a flank, six small screens were erected, one about 4 yards to the right of the muzzle of each gun, and running out about 8 yards to the front. They were about 8 ft. high. They were dismantled during the day and re-erected each night, in socketed holes.

8. *Locality imitation.*—Screens made of canvas or wire netting combined with canvas, brushwood, grass, etc., may be painted to reproduce a definite locality such as a brick wall, ruin, hedge, etc., or a general landscape.

These should only be used in places where required for a short time because the paint does not stand the weather long and they require constant watching and careful maintenance.

These screens have been used with effect as follows :—

i. Imitation brick walls painted on canvas backed with wire netting to screen a much used thoroughfare (Plate **62,** Figs. 3 and 4).

ii. Imitation hedges of a combination of raffia, canvas strips, and brushwood, on wire netting were made to conceal a battery position that would otherwise have been under direct observation. In this case an existing hedge which was too far back to be used was removed and the imitation hedge substituted for it in *front* of the guns.

9. If an area occupied during the summer is likely to be occupied during the winter months as well, the problem of screening should be considered early so that the loss of cover due to the leaves falling from the trees may be made good with brushwood beforehand, and no change be noticeable in the landscape when the trees and hedges are bare.

10. Plain screens are those that are put up without any idea of disguising the fact that they are screens. Newly erected screens always draw fire, but if the damage is regularly repaired, the attention paid to them rapidly diminishes.

These screens have been used with effect as follows :—

i. The act of screening an area or battery position before they were required drew fire from the enemy for a period during which the screens were regularly repaired.

When the screens were no longer shelled, they fulfilled the functions for which they were erected without further interference.

ii. To conceal a party working behind them.

iii. To draw fire while work was being carried out at a distance to the flank.

Although plain screening affords protection from view after the enemy has ceased to notice it, a careful reconnaissance of the area to be screened should always be made in order that full advantage may be taken of the natural features.

11. *Manufacture.*—Screens should be made up in bays of 30 ft., with supports 10 ft. apart.

In order to localize the effect of shell fire, each longitudinal width of wire netting should be suspended independently on a longitudinal wire between the uprights.

The screens are made of strips of canvas interlaced in wire netting. The strips should be 2½ in. wide, and threaded through every third or fourth mesh vertically, leaving no horizontal interval. Opacity can be considerably increased by the use of alternate vertical bands of plain and dark coloured canvas, each band being about a foot wide. There should be a strong contrast between the plain and coloured canvas. Such a screen is effective at ranges of a mile and upwards (Plate **62**, Fig. 1).

Still better results can be obtained if the colour is arranged on the vertical bands so as to produce a chequered effect.

Irregularity of outline, if necessary, can be given by not commencing the threading of every strip at the top of the wire netting, or by inserting a brushwood crown.

The material for artificial screens should be as light as possible and allow of simplicity in erection, whilst it should offer the minimum resistance to the air compatible with its efficiency for screening purposes.

12. *Erection.*—Whenever possible, screens should be attached to existing objects such as trees, hedges, houses, etc. If poles have to be used instead they should be sunk well into the ground and well guyed. The screen is fastened with staples to the poles. The uprights are joined by longitudinal wires 3 ft. apart, and cross bracing between each pair, which should be guyed in the normal way (Plate **62**, Fig. 1). These wires also form horizontal braces to the uprights which are cross braced and guyed as shown on Plate **62**, Figs. 1 and 2. Uprights should be of at least 3-in. timber. Guys should consist of at least four strands of No. 14 gauge wire, or the equivalent.

Screens should not be erected piecemeal, or unnecessary casualties from shelling will be incurred. The material should be laid out on the ground beforehand, so that the whole screen can be erected in one night.

38. Special cases

1. *Trenches.*—It is not practicable to conceal long trenches. A covering, even if perfect at the time of erection, would require maintenance out of all proportion to its value.

Short lengths of trench, such as saps, are often worth concealing, and this can be done effectually by means of covers, if sag is prevented and care is taken to conceal the spoil. The minimum width of material required is 50 per cent. more than the maximum ultimate width of spoil banks and trench. The best material is suitably painted scrim. If fresh spoil is open to direct observation, painted scrim alone is not sufficient, but must be supplemented with netting and canvas knots in order to give the necessary texture.

2. *Machine-gun emplacements.*—

i. The insignificant size of emplacements gives a wide scope for successful concealment. It is essential to restrict the area to be concealed as much as possible, and therefore, among vegetation, all spoil should be removed and traces of work concealed so that the cover over the gun itself may be almost flush with the ground, and very slightly larger than the actual trace of the emplacement.

If this is done, a light rectangular frame will be sufficient to support the covering which is capable of being moved up when the gun is in use and down at other times.

It is sometimes possible to conceal the embrasure or loophole by a combination of dummy brickwork and gauze on a hinged flap which is hitched up when the gun is firing.

It is of great importance that :—

(*a*) The cover is erected before work on the emplacement is begun.

(*b*) All evidence of activity and occupation, such as tracks, is suppressed.

ii. Materials for coverings. For grass, appropriately coloured raffia (or gardeners' bast) is best.

For bare earth or shell holes, painted scrim is sufficient.

For grass and earth a combination of raffia and scrim is suitable. Small fish nets (10 ft. by 10 ft.) garnished with raffia are very suitable. They are portable and match nondescript surroundings.

3. *Snow.*—When snow covers the landscape completely, concealment is very difficult, especially as regards the net coverings which will not hold snow and consequently show up dark squares. Blast marks are also conspicuous unless preventive measures are taken.

For net coverings the only remedy is to fit on them large islands of white calico.

Three remedies for blast marks have been applied with apparent success :—

i. Covering them up with fresh snow after firing.

ii. Covering them up with flattened chalk, supplemented where possible with snow.

iii. Prevention, by placing a stout sloping platform close under the muzzle to deflect the blast off the ground.

The use of white calico is not so satisfactory as any of the above as it is impossible to predict what size will be necessary.

As the fall of snow obliterates all previous tracks, positions, temporarily unoccupied, may be disclosed if visited by patrols. As snow over occupied positions, such as dug-outs, is melted by the warmth, steps must be taken to conceal the consequent dark patches.

4. *Camps.*—It is impracticable to *conceal* groups of huts or tents from air observation. The mere regularity of the lay-out is conspicuous.

It is pure waste of time, paint and labour to attempt to render a camp less conspicuous by means of any three-colour painting as described under "gun painting" (Sec. **33**). Daubing new tents with clay may help to reduce their visibility.

5. *Bivouacs.*—If it is essential to conceal a bivouac that must be in the open, the whole bivouac must be included under one comprehensive horizontal cover which must be strongly erected before the arrival of the occupants.

6. *Pill boxes and concrete structures* will be treated in the same way as machine-gun emplacements if concealment is essential.

Every effort must be made to break up the regular shadow of the structure, and where a cover is used, to see that its shadow blends with the general scheme.

Pill boxes may be hidden by being built inside existing cover, *e.g.* in a room, or under a shed.

7. *Artillery.*—

i. *Heavy guns.*—Railway guns can be disguised as railway trucks. It is better to adopt such disguise than to erect a colossal cover unless a good deal of natural assistance in the shape of trees, houses, etc., is at hand.

A system of area concealment, such as creating a new regular shaped field, by means of a very large area, may be necessary in certain important cases. This makes exact location of the battery much more difficult.

ii. *Gun painting.*—The object here is to destroy the gun's identity so that it may be difficult to recognize its nature from a distance. Three-colour painting (green, cream and brown) has been adopted to achieve this purpose with the idea that one or more of these colours are capable of blending with any landscape, leaving the

visible remainder as a number of isolated patches of colour and so breaking up the form of the gun into a number of dissociated pieces. All under portions must be painted light to neutralize the shadow.

iii. *Shadows* can be eliminated by using the over-all cover (*see* Sec. **36**).

iv. *Flash and sound.*—Little can be done, the cover will not hide the flash.

v. *Regularity* should be avoided as much as possible.

vi. *Blast marks* are in the shape of white fan-like patches and are quite unmistakable.

Their presence may be avoided by the guns being so sited as to fire over :—

(*a*) Water.
(*b*) A metalled road.
(*c*) Shell holes.
(*d*) Rock or limestone.

Blast marks can be hidden by :—

(*e*) Pegging down ¼-in. mesh expanded metal in an irregular shaped patch in front of each gun. One thickness resembles thin grass in a photograph. Two thicknesses resemble medium grass, and three thicknesses long grass.

(*f*) Unrolling an irregular net of wire or string garnished with canvas knots or patches over the blast mark when the gun has ceased firing. This net must be removed before the gun reopens fire.

8. *Loopholes.*—At close range (300 yards) a loophole can be made absolutely invisible by the use of gauze painted to match the external appearance of the ground or wall.

Beyond this range it is sufficient to distort the shape of the loophole. A rectangular loophole is very conspicuous. Provision must be made to prevent daylight showing through the loophole from behind and so giving its position away.

9. *Aerodromes.*—It is impossible to conceal aerodromes for any time owing to their size and constant traffic.

If sited at the edge of a wood, the pattern of the trees may be continued on to the roofs of the hangars ; the non-shadow side of the wood should be chosen so that the difference in length of shadow does not show up.

A certain aerodrome in Belgium in the Great War escaped observation for a long time. It was built on a market garden and the rectangular patches of the crops were reproduced on top of the hangars. The background being dark, the shadows did not show in the air photograph.

10. *Dumps.*—Although it may frequently be impracticable to hide a dump, either by artificial means or by siting it among trees, it should always be possible to conceal the activity in it. Information about this activity will be of use to the enemy in deducing movements of troops and stores which may indicate an impending attack. Concealment may consist of screens over the roads or railway lines which hide the trucks or lorries in use.

CHAPTER IX

PROTECTIVE WORKS IN WARFARE IN UNDEVELOPED AND SEMI-CIVILIZED COUNTRIES

39. General

1. The most important differences between protective works used in war against a trained and civilized enemy possessing strong artillery and those used in war against unorganized and uncivilized enemies, armed only with rifles and possibly with hand grenades and a few guns, are, that in warfare against the latter :—

- i. Defensive positions take the form of a continuous line of defences round the camp or cantonment, with, in mountain warfare, small posts or forts occupying those hill tops from which the enemy could otherwise fire into the camp.
- ii. Command, or the height of the parapet above the ground, is of more importance than concealment. Walls or breastworks of stone and other bullet proof materials can be used instead of trenches dug into the ground, and when time permits, small forts or blockhouses are frequently constructed.

2. The kind of defence to be used and the materials to be employed will often be suggested by the customs of the people of the country. Thus, use is made on the N.W. Frontier of India of stone sangars and stone or mud forts ; in Burma and Assam, of stockades or walls of trees or bamboos ; in Africa, of breastworks of sand surrounded with an obstacle made of thorn bushes, called a zariba.

3. *Obstacles* are an essential part of the defences in this type of warfare (*see* Manual of Field Engineering, Vol. I, 1933 (All Arms), Chapter VII).

The inner line of obstacles must be outside bombing distance.

40. N.W. Frontier of India—general remarks on protective works

1. The protective works used during operations on the N.W. Frontier of India are generally made of stone in the

form of walls, called sangars. This is because stone is plentiful and the ground is generally hard to dig. Although stone walls are the best form of permanent protection, where the ground is suitable it is quicker to dig trenches for protecting sites occupied for short periods only. Sometimes it may be quicker to combine a shallow trench with a low wall to obtain the necessary cover for firing in the standing position. In such a case the upper part of the parapet will usually be revetted with stone or other material. A ditch outside such a breastwork will add considerably to its power to stop a sudden attack.

2. The protective works constructed by troops during operations will include :—

i. Sangars for temporary road protection piquets (route piquets).
ii. Sangars for night piquets round temporary camps and for " permanent " piquets for road and camp protection.
iii. Defensive perimeters of camps.
iv. Defended villages.
v. Blockhouses for holding special points.

41. Construction of sangar walling

1. Sangars need careful construction to be bullet proof and rigid.

2. The foundation of the wall is most important. No wall will stand for long on sloping ground.

If the slope is at right-angles to the length of the wall, the foundation must be dug out level, as shown in Plate **64**, Fig. 1.

When the slope runs in the direction of the length of the wall, it must be cut into horizontal steps, as shown in Plate **64**, Fig. 2.

3. Only the largest stones that can be comfortably manhandled should be used for building the wall. They should be built as far as possible in courses, like sandbag revetments, and the stones of one course must break joint with those of the course below, as shown in Plate **64**, Figs. 3 and 4.

Owing to the stones being all of different sizes a sangar wall cannot be arranged in alternate courses of headers and stretchers like a sandbag wall. Any specially long stones should be selected for use as " bond-stones," as shown in Plate **64**, Fig. 4.

These stones tie the wall together and prevent the face of the wall from falling outwards. If stones long enough to go right through the wall cannot be found, smaller stones should be overlapped. If the stones are difficult to bond, brushwood and wire assist.

Chips and small stones can be used for filling in the gaps between the large ones. Earth must not be used for this purpose. Plastering the wall outside with a mixture of mud and chopped straw makes an effective weatherproof skin.

4. To be bullet proof, walls must not be less than 2 ft. 6 in. thick at the top and they should be built with a slope on each face of 4/1.

For rapid building, the wall, if it is to be 4 ft. 6 in. high, should be 3 ft. to 3 ft. 6 in. broad at the bottom and the sides should be nearly vertical. Whenever possible, however, the wall should be made 5 ft. broad at the bottom, especially if there is any chance of its having to be increased to 6 ft. in height later.

5. To resist shell fire the sangar should be constructed as shown in Plate **66.**

To minimize the effect of splinters and ricochets a course of sandbags, filled with stones, is laid on the tops of all walls. On top of these sandbags large irregular stones are placed to give head cover. Sandbags, if bullet-proof, may be used, but stones are better.

6. Drainage must not be forgotten and drain holes must be left through the foot of the wall during construction ; the holes must be sufficiently large to allow them to be cleared when they become closed up with mud.

7. The working party for construction may be divided into parties of eight, where stone is within 50 yards of the job : 2 builders, one inside, one outside the wall, and 6 carriers.

A party, with crowbars, may sometimes be required for breaking up rock.

42. Sangars for temporary route piquets

1. Route piquets are small piquets put up by the advanced guard and withdrawn on the same day when the column has passed. Such a piquet will only be in position for a few hours of daylight, and will usually be distributed in small parties over a considerable area.

In this case protective works will consist of the combination of a shallow excavation and a low wall formed by drawing a few large stones together. The work will often have to be carried out by men in the lying position.

2. Concealment is important and men must be taught not to make conspicuous sangars by piling one small stone on another, as they are apt to do.

3. There will be no time or material to make an obstacle.

43. Sangars for camp or permanent piquets

1. *Siting.*—The general position of the piquet will be decided by the force commander, the exact siting being decided after a reconnaissance of the ground, by the commander of the troops detailed to occupy it.

As in all defences, the first requirement in siting a piquet is that it should allow the garrison to carry out the fire task allotted to it. This task will be :—

- i. To prevent the enemy from using the top of the hill (or the approach), to guard which the piquet has been detailed.
- ii. To prevent snipers or small parties from passing between the piquets to fire into the camp or to attack convoys.
- iii. To assist the occupation of temporary positions by route piquets.
- iv. To watch areas of country for "movement by tribesmen."

The second requirement to be met in siting the piquet is that the garrison shall be able to hold the sangar against attack.

The third requirement is that the piquet should be in view of the camp or of the road that it is protecting.

In order that the garrison can carry out its fire task, it will sometimes be necessary to divide the piquet into two parts either in separate sangars or into sangars connected by a communication, but this should be avoided if possible.

To resist attack, the piquet should be on the highest ground in the vicinity. If it is not, a parados is required, the construction of which wastes time and labour.

Plate **65,** Fig. 1, shows a piquet standing on the top of a hill where there is no higher ground within rifle range and where the ground falls on all sides. In such a position it is evident that no parados will be required.

Plate **65,** Fig. 2, shows a piquet standing on a spur which can be fired into from higher ground on the left. By putting the piquet down the hill on the right-hand side of the small knoll "A," the wall at "A" can be made to act as a parados for the wall at "B," and no separate parados need be made.

The position of the piquet in the above figure would be very dangerous if the enemy could fire into the sangar from a hill across a valley. In such a case the piquet would have to be sited and a parados made as in Plate **65,** Fig. 3.

These two parados will generally be enough, as it can very seldom happen that a piquet is commanded by ground on more than two sides. Plate **67** shows the plan and section of a sangar in a position such as that shown in Plate **65,** Fig. 3.

In order that the piquet shall be in view of the camp or road it is protecting, it may also be necessary for the piquet to be divided if the hill top is very broad, but such an arrangement is very undesirable.

2. *Design and dimensions of sangar.*—

i. The trace or plan of the sangar will depend on the shape of the ground and on the fire task of the piquet.

A circular sangar is the quickest to build and gives an equal amount of fire in all directions. Circular sangars are particularly useful for camp piquets that will be required for a few nights only. The parados, if required, will take the form of an inner circular wall at a distance of 3 ft. inside the parapet wall. Plate **67** shows the plan and section of a circular sangar.

ii. When a tent has to be pitched in the sangar, as in "permanent" piquets, the circular shape is not convenient. The usual shape is an oblong with the corners rounded off, as shown in Plate **68.** The fire from the corners of such a sangar is weak.

iii. The size of the sangar depends on the size of the garrison told off to occupy it. A strong garrison will usually be detailed when the piquet is first built, the strength being reduced when the sangar and obstacles have been completed.

A rule that is generally used is to give 1 yard, measured along the inside of the parapet wall, to each man of the garrison in a new or temporary piquet.

When the sangar is completed with parados, traverses, obstacles, etc., 2 yards to each man, excluding officers and N.C.Os., can be allowed.

Permanent piquet sangars have to be large enough to take a 160-lb. tent, and to allow a communication track at least 3 ft. broad between the tent and the inside of the parapet or back of the fire step or traverse. The tent requires a space of 16 ft. by 16 ft. ; the smallest size for the sangar is, therefore, 22 ft. by 22 ft., that is, a perimeter of 88 ft. To allow a fire step and traverses to be built later, the size of the sangar must be increased by 2 ft. all round, making the smallest sangar 26 ft. by 26 ft. with a perimeter of 35 yards.

An extra 6 ft. of length, or 4 yards of perimeter, will be required for each parados such as that shown in Plate **68.**

iv. The parapet walls must allow of the garrison firing standing. They should therefore be about 4 ft. 6 in. high when first made. They must allow of men aiming at the foot of the inner line of obstacles. If the line of fire is very much down-hill the wall will have to be made lower. If the line of fire is up-hill it may be made higher. It should be tested everywhere with a rifle.

On the first day there may not be time to build the wall to this height, but nothing less than a 3-ft. wall with a good obstacle outside it must be allowed. With such a wall the extra height for fire, standing, can sometimes be obtained by digging a shallow fire trench.

As soon as possible a fire step should be added to the 4 ft. 3 in. or 4 ft. 6 in. wall, and the wall should be raised to 6 ft. 6 in., so as to give cover for men moving about in the sangar.

v. Traverses may be required to protect men using the long sides of the sangar from enfilade fire. They are shown in Plate **68.** In order to protect the firers they must be 1 ft. to 1 ft. 6 in. higher than the parapet.

vi. The entrance of the sangar will be on that side from which there is the least danger. When the sangar is first built the entrance will be an opening 3 ft. wide which will be filled up with stones at night. Later, a wing wall, as shown by the dotted lines in Plate **68,** will usually be built to cover the entrance. Care must be taken that this does not hide any of the inner belt of obstacles from the view of the sentries.

vii. A wall is usually built round the tent. The tent should be carried over this wall, as shown in Plate **68,** Fig. 2. so that a bomb thrown at night may roll into the communication track where it will not kill the men in the tent.

viii. The sangar should be improved by the garrison, arrangements made for flanking fire and covering provided for day latrines, rations and water. A sloping roof of wire netting provides a good protection against grenades.

ix. The question of drainage inside the wall must be considered and steps taken accordingly from the outset.

3. *Loopholes.*—

i. A loophole, 1 ft. square and 2 ft. above the ground, will be required for lamp signalling to the next signal station. Other loopholes may also be required for sentries, light machine guns, etc.; great care is, however, required in siting and constructing them in order that they may not be a source of danger. They should only be put in for some special purpose.

ii. Loopholes are not easy to make unless timber, or prepared box loopholes are available. They can be made with large stones if available. The opening on the outside of the wall should be as small as possible and double curtains should be provided to prevent light showing through when the loophole is in use. A stone must be provided to place in the loophole to stop bullets coming in when the loophole is not in use.

iii. Loopholes are usually placed low down in the wall at fire-step level, *i.e.* 1 ft. 6 in. to 2 ft. above ground.

4. *Construction of the sangar.*—The stages of construction may be as summarized below :—

i. Before leaving camp, requirements of men and tools should be forecast as accurately as possible.
ii. Reconnaissance of site.
iii. Marking out the trace of first, the wall, and secondly, the obstacles.
iv. Working parties detailed.
v. Building of walls and obstacles should then start together, commencing with the most dangerous side.
vi. 3 ft. of wall must be completed, together with efficient obstacles, before work is stopped. If material is readily available, 4 ft. 6 in. of wall should be completed.
vii. A signal loophole *must* be included in this height.
viii. Stores and spare materials are then collected within the sangar.

5. *Time and labour required.*—

i. The party and tools required for wiring depend on the length of fence that it is hoped to construct on the first day. It depends also on the hardness of the ground. If holes for the pickets have to be made in rock, engineers may be detailed to help. Two engineers will probably make two to six holes in an hour, according to the hardness of the rock.

The actual wiring of the pickets will take a very short time if the troops are properly trained. Arrangements to close the entrance through the wire at night must not be forgotten.

ii. In addition to the building, carrying, stone-getting and wiring parties, the following must be arranged for :—

(*a*) Digging foundations for walls, as described in Sec. **41,** levelling the ground inside the sangar and filling sandbags for the top of the walls.

(*b*) Carrying up the piquet stores, *e.g.* ammunition, water, rations, tent, etc., and, if necessary, for (*c*) Clearing ground round the piquet site. (This may take from 20 to 200 men.)

(*d*) Making a path for pack animals up to the sangar.

A path for animals up to a permanent piquet must always be made as soon as possible; if this can be made at once it will save the labour of men employed in carrying up the piquet stores.

As a rough guide, it may be assumed that when materials are available within 50 yards of the site of the sangar, six builders and eighteen carriers, with six picks and six shovels, can construct a sangar of the type shown in Plate **67** for 20 men in 4 hours.

44. Defensive perimeters of camps

1. Protection must be provided round the outside boundary or perimeter of camps. This will consist of a stone wall breastwork of minimum height 4 ft. 6 in. This minimum height is desirable to provide cover for animals and for the occupants moving about inside the camp, but should materials not be available the protection may consist of a lower wall with a trench inside it or of a trench alone.

2. The corners of the camp must be rounded. If this is not done there will be some ground at each corner that is not covered by fire.

All entrances must be covered by a traverse inside and arrangements must be made for blocking them at night. Movable knife rests are most suitable for this purpose.

Traverses and a parados should be added to the perimeter when time permits, and cover should be prepared for the local reserves.

There should be an obstacle all round the camp. Even a single wire is better than nothing.

The defence of the perimeter is based on enfilade fire of machine guns and light machine guns along the front of the perimeter. The obstacle should, if possible, be so arranged in zigzags that the machine guns fire along it.

3. In the main camp of a force there are generally enough troops to man the whole of the perimeter. But in camps on the lines of communication, where there are always few troops but many transport animals and large stores of rations, there will not be enough men to hold the whole of the perimeter. In such camps the troops in the first line are placed in small posts like "permanent piquets" at intervals along the perimeter, and the space between these posts is closed by obstacles along which it is arranged that the posts can fire without hitting one another. A second line of posts is sometimes placed in rear, or there is a continuous perimeter as in other camps.

4. Inside camps, cover from fire is required for headquarters and hospitals. The floors of tents should be dug down 2 ft. to 3 ft. so that all men sleep below ground level, adequate surface drainage being allowed for. Sometimes houses can be used for these purposes. They must be well cleaned out before being used and extra windows will usually be required for ventilation.

45. Stockades and blockhouses

STOCKADES

1. *Stockades* are walls made of timber or bamboo. They are much used in the jungle countries on the northern frontier of Burma and Assam, and in West Africa, where the enemy has not yet obtained small-bore rifles.

2. The stockade need only be made proof against the kind of weapon used by the enemy. It should usually be high enough to prevent the enemy from climbing over it easily. Two or three strands of barbed wire attached to *inclined* brackets at the top of the stockade will add considerably to the difficulty of surmounting the stockade, particularly at night. Fire is usually from a fire step, through loopholes, which are placed at least 6 ft. 6 in. above the ground so that the enemy cannot fire through them. Arrangements for flanking fire along the face of the stockade must be made. Obstacles should, of course, be used when possible.

Some means should be provided for lighting up the front of the stockade in case of night attack. Flood lighting will very rarely be practicable, but torches, bundles of leaves or shavings, or other inflammable material should be improvised and kept ready to be lit and thrown from behind the stockade.

BLOCKHOUSES

3. *Blockhouses* are small isolated buildings prepared for defence; they are only suitable for occupation if the enemy has no artillery. Their chief use lies in the economical protection of communication generally and important points in particular, such as bridges, tunnels, defiles, pumping stations, halting places, depots, convoy meeting places, railway stations, camps, etc. Permanent masonry blockhouses are in extensive use in India on the frontier and elsewhere for some of the above named purposes.

4. Semi-permanent blockhouses are usually made of a combination of wood or corrugated iron and shingle in which a dwarf rubble wall or bank of earth supports two corrugated iron skins 6 in. apart, packed with hard shingle, loopholed as required. The roof is composed of corrugated iron or a tent, the whole structure being supported on a wooden frame. The entrance is partially underground and protected by a traverse.

A circular fire trench should be provided for the sentry, and a wire entanglement constructed round the completed blockhouse; provision must be made for the storage of water.

5. Blockhouses can equally well be built of dry stone walling. If the bulk of the stones are round, the walls are very apt to collapse. To prevent this, brushwood may be inserted in the wall to form a bond. Alternate layers of stones and brushwood have been found very effective. If liable to be fired into from hills near by, the roof should be made bullet proof; if protection from weather only is required the roof may consist of a tarpaulin or any other material available. The shape of a blockhouse is immaterial so long as it allows fire to bear in the requisite directions, but to economize labour, the design should permit available lengths of corrugated iron to be embodied without cutting.

6. In sandy countries breastworks of sand and thorn zaribas may be used.

Where railway stations have to be protected blockhouses, stockades and splinterproofs made of rails and loopholed buildings will predominate.

7. An important role for blockhouses is the protection of a line of railway running through hostile territory in desert warfare.

A type of blockhouse that has been used with success and that can be quickly constructed is shown in Plate **69**, Fig. 2.

It consists of a circular wall of sandbags with a palm leaf or corrugated iron sheet roof. A water tank protected by sandbags is included. Working along a line of a railway a Field Company R.E. can construct four such blockhouses a day at the normal distance apart of 800 yards. The construction train with its infantry escort should arrive as soon as possible after daylight, with the complete stores for each blockhouse (*i.e.* sandbags, roof material, water tank, wire and pickets) in its own trucks. The train is stopped at the site for the first post (previously reconnoitred) and the stores for the blockhouse unloaded together with its working party. This consists of a section of engineers together with ten infantry, if available, for filling sandbags, etc. The train then proceeds to the other sites in turn, and the process is reversed at the end of the day's work. The infantry escort usually remains behind to garrison the newly completed posts, which become the head of the blockhouse line. During the day the R.E. officer in charge should reconnoitre sites for the posts to be constructed next day.

8. Plate **69**, Fig. 1, shows a type of permanent blockhouse or tower used on the N.W. Frontier of India. It is square in plan and built of stone or brick in two floors.

In the upper floor the men fire over the top of the wall. Means must be provided for flanking fire to be brought along the walls either by special steel overhanging loopholes as illustrated or by overhanging galleries built of corrugated iron and shingle.

Entrance is by a ladder to the first floor. The lower floor has no openings except the loopholes, which are kept as high as possible to prevent a rifle being used by a man standing outside, and also to make the garrison safe from distant sniping during the day.

PART III—BRIDGING

CHAPTER X

BRIDGING OPERATIONS

46. Requirements and equipment

1. The bridging requirements of an army, determined by tactical considerations, are divided into six load groups.

i. *Assault*, for the passage of assault troops to seize a footing on the far bank.
ii. *Pack*, as above, but including pack animals.
iii. *Light*, for close support weapons and vehicles to support the advanced troops.
iv. *Medium*, for all divisional loads.
v. *Heavy*, for all loads normally with the army in the field.
vi. *Super-heavy*, for any abnormal loads exceeding the limits of v.

2. The military loads in these groups are given in Field Service Regulations, Vol. II, 1935, Appendix VIII. The governing loads to be used in the design of bridges are shown in Appendix IV.

3. For each of the groups i, iii, iv and v (above), one or more forms of mobile bridging equipment provided with its own transport, exists. A list of this equipment and its distribution in the army is given in Field Service Regulations, Vol. II 1935, Appendix VIII.

The Kapok assault bridge is described in the Manual of Field Engineering, Vol. I (All Arms). The folding boat equipment, the small box girder and the pontoon equipment in Military Engineering, Vol. III, Part II, Pamphlets Nos. 2, 5 and 3 respectively.

4. The mobile equipment is limited in quantity and must, therefore, be repacked on wheels as soon as possible.

To replace it, if the crossing is to remain, there are two more classes of bridging equipment :—

i. The temporary.
ii. The semi-permanent.

These two classes are non-mobile in that they are not provided with their own transport vehicles but are held in engineer parks ready to be despatched on army transport made available when required.

5. The temporary type is provided by the large box girder bridge described in Military Engineering, Vol. III, Part II, Pamphlet No. 1.

In the semi-permanent class short spans, up to the limit of length permissible on transport vehicles available, are dealt with by means of steel joists. Above this limit girders that can be built up on the site are necessary. The Inglis and Hopkins bridges are examples of types used in the Great War, but new types are under consideration.

6. Owing to the complicated structures required to carry modern military loads it is necessary, in the interests of speed, to use equipment wherever possible.

Occasions will occur, however, when equipment is not available and engineers must then be ready to improvise.

47. Sequence of bridging operations in mobile warfare

1. The passage of a river against opposition is an operation that calls for many preparatory measures. Speed is almost invariably one of the chief elements of success. The equipment units are normally moved in rear of leading formations. Their availability at the time and place required demands careful staff work based on engineer information. Maps, intelligence reports, air reconnaissances and air photographs, provide material upon which to base the preliminary distribution of bridging equipment and for the selection of places upon which to concentrate the ground reconnaissance. The plan is gradually evolved as information is collected and it will seldom be possible to await the collection of all information before making some move with the equipment. Much depends therefore upon the engineer knowledge of the capability and limitations of the equipment in the conditions of the operation contemplated.

2. In mobile warfare the normal sequence of operations will commence with the passage of infantry to secure a bridgehead. For this purpose there is available the folding boat equipment and the Kapok assault bridge. Kapok is intended for crossings not much over 100 ft. in width. For night work this figure represents generally the maximum width that should be attempted by direct launching. Slow running currents not exceeding two knots are best.

The folding boats are less affected by the strength of the stream and are not limited by its width. Although they do not pass a continuous stream of troops across, they can be used simultaneously at a number of places and the landing place on the far bank can be varied at will. Further they can be launched in many places where Kapok would be impossible.

3. The assault troops having crossed and established a bridgehead, the next problem is the passage of the close support weapons and vehicles required for their suppport.

The tracked raft of the folding boat equipment meets this need where the first-line transport of the infantry is mechanized. For horse transport and for the heavier loads of the light load class, the decked raft or bridge has to be used.

Where the river is within the limits of a bridge (112 ft. for one infantry or half one cavalry set of equipment) it will be better to make a bridge than to use decked rafts. The extra time required to build the complete bridge will be set off by the much more rapid transport over the bridge.

4. As soon as sufficient bridgehead has been obtained bridges will be required for heavy or medium loads. Both these requirements can be met with the pontoon equipment.

5. Finally, there is the problem of the dry gap, the demolished road bridge, and the road crater. The small box girder bridge provides a medium crossing up to 64 ft. over both wet and dry gaps.

48. Improvised bridges

Should the service equipment not be available or, as may be the case in undeveloped countries, unsuitable, bridges will have to be improvised.

Chapters XV to XVIII deal with this subject.

49. Selection of site

1. The final choice of a bridge site should always be made on the ground. Apart from tactical considerations, which may be of great importance in the case of an assault crossing, the following points must be considered.

IN THE CASE OF AN ASSAULT CROSSING

2. *For the Kapok assault bridge.*—

i. Width of river. This should not normally exceed 100 ft. unless special measures can be taken to guy the piers.

ii. Speed of current. If it exceeds 2 to 3 knots, difficulty will be experienced in launching the bridge and keeping it straight.

iii. Height of banks. 3 ft. is about the maximum height permissible.

iv. Suitable building site. A reasonably level and straight piece of ground somewhat longer than the bridge is essential.

v. Suitable ground for carrying the bridge from the building site to the launching place. Sharp turns must be avoided and the final carry must be straight at least for the width of the bridge.

3. *For the folding boat equipment.*—

i. Nature of banks, which should not be more than 2 to 3 ft. high for the boat ferry.

ii. Site for off-loading stores out of hearing from the enemy and suitable cross-country route to the starting point near the river.

iii. Width of river and speed of current, which will affect the time for the crossing.

iv. Where bridge or decked rafts are used, suitability of river bottom for trestles. This should be gravel and reasonably level. Other points that will affect the bridge are dealt with below.

FOR ALL TYPES OF BRIDGES

4. *In the case of both wet and dry gaps.*—

i. Approaches.—As the approaches often take longer to construct than the bridge itself, they will bear a very important part in the selection of the site. They should, if possible be :—

(*a*) Straight for at least 50 yards on each side of the bridge.

(*b*) Level, or at a grade not exceeding 1 in 20.

(*c*) Selected so that the minimum amount of work will have to be done on them.

As a rule, the site with the best approaches will be reserved for the semi-permanent bridges.

ii. Width of gap.—Other things being equal, the narrowest gap should be chosen and one that needs the least amount of work on intermediate piers.

iii. Depth of gap, if intermediate piers are necessary.

iv. A skew span should be avoided if possible as it complicates design and needs more equipment.

5. *In the case of wet gaps only.*—

i. Permanency of channel, liability to flood and freedom from scour.

Straight reaches should be chosen that are not in the proximity of sharp bends or islands, unless these are used for foundations for piers. Scour is worst near bends.

The banks must be sufficiently high to confine the water to the main channel during flood periods. A hard bottom and banks of gravel indicate permanency of the channel.

The highest flood level is often marked on existing bridge piers. Information regarding floods can be obtained from local inhabitants or publications. The nature of the country will give an indication of the liability to flood.

The bottom of girders must be kept above highest flood level except when speed of construction is of paramount importance. This factor may seriously affect the approaches.

ii. The nature of the bottom if piers are required. A gravelly bottom should be sought.

iii. The rise and fall of the tide in the case of a tidal river. High tide level will be indicated by marks on the banks or drift caught in bushes, etc.

iv. Strength of current. For floating bridges a quiet reach away from sharp bends is desirable. The rate of current may be measured by selecting a straight length of 15 to 20 yards, where the channel is fairly uniform and there are no eddies.

Drop in a chip of wood and find the time it takes to travel a measured distance. This gives the surface velocity (measured in feet and seconds). The mean velocity will be $\frac{4}{5}$v. ft. a second or $\frac{6}{11}$v. miles an hour.

50. Measurement of the gap

1. *For both dry and wet gaps*, drive in two pickets A and B on the near bank about 3 to 4 ft. apart along the centre line of the proposed bridge, and level them with a spirit level. On the far bank drive a third picket C and level it with pickets A and B by means of a telescopic level if available ; if not, by sighting. Boning rods may be used on top of the pickets to assist sighting.

The difference in the heights from the ground of the inside picket A and picket C will be the difference in level between the two banks.

Stretch a line as tightly as possible between pickets A and C, and tied to the pickets at the same distance from their tops. This line should be marked at every 5 ft., or convenient distance, of its length by a knot or a piece of white tape *securely* tied to it. This enables the horizontal distances to be read off from picket A without any further measurement. This method avoids shouting between the boat and the bank.

2. *In a dry gap*, any available rod marked clearly in feet and inches should be erected immediately under the marked points on the span line. The depth at these points should be read with a telescopic level, but if this is not available they may be read by sighting between pickets A and C, boning rods being used. In no case should they be read to the span line, since this would give an incorrect reading due to sag.

3. *In a wet gap*, the vertical readings should be taken from a boat, wherever possible, with a 6-ft. rod, a boat hook or a line and plummet. If a line is used, it should be marked at every foot of its length with a knot or piece of white tape. Readings should be taken to the water level and the difference in level between the water and the top of picket A added.

4. *If no boat is available*, prepare two more lines, one slightly longer than the distance between pickets A and C and the other twice as long. Attach one end of each of these to a ring, which is allowed to slide freely along the span line (Plate **70**).

Fix a small pulley-wheel to picket C. Pass the longer of the two lines attached to the ring round this pulley and bring it back to the near bank.

Pass a plumb line through the ring. It must be more than long enough to stretch the full span and still sound the greatest estimated depth at the far bank.

By paying off on one line and taking in on the other, the ring will travel across the stream. When the ring reaches each marked point on the span line, take vertical soundings with the plumb line, by measuring the amount which runs out before the plummet comes to rest.

There will be a considerable error due to the sag in the span line. This sag should be checked with a telescopic level, if available. But a very fair estimate can be made by eye, by estimating the height of the span line above water level. If the plumb line is clearly marked, it will be possible to read this height on it from the bank.

This method is only possible in daylight and if both current and wind are slight.

5. *Width of water obstacle.*—When it is desired to measure the distance across a water obstacle without going to the far bank, the method given in Sec. **4**, 7, may be used.

6. The following is a rapid method of measuring gaps up to 75 ft. without apparatus of any sort.

Choose an object A on the far bank (a tuft of grass will often be enough), place a stick opposite it at B. Place a man C in line with A B, so that B C is about equal to the width of the river.

The observer O places himself at a convenient distance, so that the angle ABO = 90 degrees. To do this it is quite sufficient to estimate when A and C are equally distant from him.

From O the exact position of C is obtained by spanning with the hand as follows :—

i. Holding the hand at arm's length—back towards one—spread the fingers until the thumb just reaches to B, and the little finger reaches to A.
ii. Now move the arm towards BC, and move C until BC spans the same as AB.

Then BC = AB.

Using the above method gaps up to 75 ft. may be measured quickly, and with an error not exceeding 3 per cent. Beyond that width the advantage of speed and simplicity becomes hampered by the size of the triangle OBC.

51. Organization

1. The primary requirement in all military bridging operations is speed and this is dependent on good organization. The best method of using the available resources in materials, labour and transport and the organization of the whole require to be most carefully thought out beforehand in detail, whether the operation is large or small.

A definite programme of work for the whole operation must be drawn up before work commences. This should be made out in tabular form, called a *work table* (*see* Appendix II). The amount of detail required will naturally depend on circumstances.

2. *Labour.*—The work table should show :—

i. The allotment of labour to each task.
ii. The estimated time for each task.
iii. The order in which the tasks are to be carried out.

Men should be detailed direct from one task to another. This means that the N.C.O. in charge must be continually looking ahead. Tasks that will hold up others and work that will take longest to complete must be started first.

3. In nearly every case labour will be available before the materials arrive and often before the design is completed. No time should be wasted, for there is always work that can be started at once, such as :—

i. Preparation of accommodation and latrines.
ii. Clearance of debris interfering with construction.
iii. Construction of a temporary crossing to take stores to the far side of the gap.
iv. Setting out (*see* paragraph 7, below).
v. Work on the approaches.
vi. Clearing ground and erecting derricks for unloading stores (*see* paragraph 10, below).
vii. Excavation for bank seats and piers, and, if possible their construction from materials available locally.
viii. Preparation for erection of the launching gear. The ground should be prepared for anchorages and winch-beds, and, if possible, these should be constructed out of local materials.
ix. Preparation of notice-boards.

4. Work should normally be arranged by *shifts*. The duration of a shift will depend on the nature of the work. If the work is not heavy, men can work continuously for 8 hours, but for continuous heavy work men cannot be expected to work for more than 6 hours at a stretch, and may even lose efficiency after 4 hours. The only factor normally to be considered when deciding the duration of a shift is the earliest possible completion of the task.

When one shift is handing over to another, the men of the incoming shift should be detailed to their work before the outgoing shift ceases work. Each man of the outgoing shift hands over his tools to the man taking over from him and points out to him the state of the work in hand.

5. *Task work* is always to be preferred, but is not always practicable in bridging operations. In any case, sections, etc., should be given definite jobs and kept as far as possible on the same work. All men must be made to realize their personal responsibility for the correctness of their own particular task and for the speed with which the whole operations are completed.

6. *Orders* should be acknowledged by a salute (if the service cap is being worn) to show that the order has been understood. If the cap is not being worn and the recipient of the order is not within close speaking distance, he should acknowledge the order by raising the arm vertically above the head.

In all bridging operations, particularly when handling heavy weights, absolute silence, except on the part of the officers and N.C.Os. in charge, is essential. Failure in the *immediate* observance of an order may result in a serious accident or in disaster to the bridge.

7. *Setting out* should be commenced as soon as the design of the bridge is sufficiently advanced.

A centre line is laid out and permanent reference points put in clear of the work. The marks must be clearly made and must be so secure that their position will not be altered during the early stages of construction.

The position of the anchorages, bank seats, etc., should be taped out, and also, where necessary, the sites for the rollers and the packing for girder erection.

Whenever possible, a steel tape should be used. If linen tapes have to be used, they should be very carefully checked to ensure their accuracy. Every effort should be made to avoid using linen tapes, string, etc., when measuring out the position of piers.

8. *The estimate of time* for completion of the task is based on the work table. If the time available is insufficient for making out a full work table, each item of work should be jotted down together with the number of men that can be fully employed on each shift. Thus an approximation of the working hours is obtained.

An allowance for unforeseen contingencies of from 10 to 50 per cent. must be made, depending on the type of work, the duration of the operation and the accuracy of the estimate.

9. *Tools and materials.*—The amount of bridging equipment available is limited, and should be supplemented by improvisation from materials available locally, such as :—

i. Materials for floating piers—boats, barges, barrels, petrol tins and oil drums.
ii. Building materials—timber, bricks, stone, joists, old girders, ladders and scaffolding.
iii. Road material—gravel, ballast, soling, planking.
iv. Sleepers, rails, telegraph poles and wire.
v. Power appliances—air-compressors, power saws, welding sets and crane hoists.

vi. Tools of all descriptions.
vii. Saw-mills, garages and workshops generally.
viii. Transport of all descriptions.

Separate stores lists must be made out for each source of supply. These must be very carefully compiled to ensure that no materials are omitted. The order of priority must be clearly shown unless all stores are due to arrive at the same time.

From 10 to 50 per cent. of spares should be demanded, the amount depending on the nature of the material, the accuracy of the estimate and the liability to damage.

As far as possible materials should be prepared in workshops where power tools are available. R.S.Js. and large sizes of timber should be cut to length and holes bored as necessary. Accurate specifications must be given to ensure that there is no delay in fitting the stores together on the site.

The fullest possible use should be made of all power appliances, such as power-saws, compressors, derrick lorries, etc., whether equipment or obtained from local resources, in order to economize in labour and time.

Tools to supplement those available with the unit will be required, such as saws, ratchet drills, augers, etc.

All demands must give the correct detailed nomenclature of the materials required.

Arrangements for the sharpening and storage of tools must be made.

10. *Unloading stores.*—An area for unloading stores must be selected and prepared. It should be as close as possible to the place at which the stores will be wanted and conveniently situated for lorries to manœuvre and turn.

A light derrick made out of a telegraph pole or some similar arrangement will often be required for unloading.

If the space is confined, the number of lorries at the bridge site at one time must be limited, and a lorry control point established where lorries should be detained until they are required at the site.

11. *The organization of the site* must be very carefully thought out in order to avoid congestion. The officer or N.C.O. in charge should visualize the process of bridge construction from beginning to end and so ensure that tasks arranged to take place simultaneously do not mutually interfere.

A site plan (Plate 71), should always be drawn, and on it should be shown everything that takes up space at the bridge site, *i.e.*—

i. All natural and artificial obstacles.
ii. The site of the bridge and approaches.

- iii. Space required for the unloading of stores, including exits and entrances, lorry turning points, and unloading derricks.
- iv. Areas allotted for girder construction, trestle construction, etc.
- v. Areas allotted for the laying out of stores.
- vi. The lay-out of all launching gear, showing the position of anchorages, winch-beds, derricks, etc.
- vii. Any temporary crossing.
- viii. Latrines, temporary shelters, etc.

Arrangements must be made for getting stores required on the far bank across the gap, whether it is a wet or dry gap. A temporary crossing, rafts or a ropeway, may be necessary.

Work on the approaches should be completed as early as possible, since it interferes with bridge construction. It will often happen that the completion of the approaches will take longer than the bridge itself.

12. *Traffic control.*—As traffic can only move in one direction at a time over a military bridge, a system of block working must be arranged, unless up and down traffic bridges with separate approaches are constructed.

The engineer unit detailed for the construction of a bridge is responsible for the provision of notice-boards showing the class of traffic for which it is designed. Boards must be erected not only on both sides of the bridge, but also at the turnings off the main road to the bridge approaches, stating the heaviest loads that can cross, the intervals, if any, they must keep, and any limitations as to speed.

13. *A maintenance party* will always be detailed to maintain the bridge fit for traffic after construction.

Frequent inspections of all parts of the bridge for any signs of failure should be carried out. The party should replace immediately any damaged materials, or parts that show signs of failure.

Any damage that puts the bridge either partially or wholly out of action must be immediately reported.

The maintenance party will be responsible for the tending of anchors, adjustment of trestles and shore bays and for the maintenance of any covering to the decking such as straw, sand, etc., and for the maintenance of the immediate bridge approaches.

CHAPTER XI

CORDAGE, WIRE ROPE AND CHAINS—BLOCKS AND TACKLES

52. Cordage

1. *Types and uses.*—The term rope is used for both fibre and wire ropes, while the term cordage is used to denote fibre ropes only.

Cordage stretches very considerably under load; the stretch in a new rope, when subjected to its working stress, is about one-twentieth of its length. This is normally a disadvantage, but in certain classes of work this elasticity may be an advantage.

The size of a rope is denoted by its circumference in inches and its length is measured in fathoms. The standard length of a coil of fibre rope is 113 fathoms.

Cordage is made from the fibres of manila, hemp, sisal and the coconut husk (called coir).

i. *Manila* is the type most commonly used. It stands exposure to weather and damp better than hemp and sisal, and is not so liable to kink. It is softer and more pliable than other types; the best quality is stronger than any other fibre rope.

ii. *Hemp* is harder and less pliable than manila. It is often tarred to preserve it from the weather. Italian hemp is about equal in strength to the best quality manila, but is little used on account of its cost. European and Indian hemps correspond to a second grade manila.

iii. *Sisal* is an Empire product and is coming increasingly into use. It is coarse and rough to handle and equal to a low grade manila in strength.

iv. *Coir* is very much weaker than other fibre ropes, but is also much lighter. It will float in water.

v. *Spun yarn* is made of from 3 to 9 yarns, any type of fibre being used. It is not a laid line and therefore has a tendency to untwist. It is issued in coils of 56 lb. weight; 5 fathoms of nine-yarn or 11 yards of three-strand spun yarn weigh about 1 lb. It is used chiefly for seizing and mousing (*see* Sec. **53**, 3, vii).

2. *Construction.*—Several fibres twisted together form a yarn, several yarns twisted together form a strand and three or more strands twisted together form a rope.

The system on which the strands forming a rope are twisted together is called the *lay*; the *angle of lay* is the angle between the direction of each strand and the direction of the centre line of the rope.

Increasing the angle of lay makes the rope weaker and less supple, but more durable against wear. The types of lay are :—

Type of lay	Normal angle of lay
3-strand (plain or hawser laid) ...	37 degrees, right-hand.
4-strand (shroud laid)	39 degrees, right-hand.
9-strand (cable or water laid) ...	37 degrees, right-hand for the strands, and 31 degrees left-hand for the three ropes.

In the trade, plain or hawser laid ropes are also called shroud laid.

Cable laid ropes are not generally used in sizes less than 5-in.

Tarred rope is about 10 per cent. heavier than white rope of the same size; care must, however, be taken that the tar used contains no chemicals that will rot the rope. If white cordage receives proper care and storage, it should not deteriorate.

To identify a piece of cordage, the material, lay, whether tarred or white, the size and breaking load must be specified.

3. The *weight* of cordage varies with the lay, but is approximately :—

Tarred hemp	$0{\cdot}19\ C^2$ lb. a fm.
White manila	$0{\cdot}15\ C^2$ lb. a fm.
Sisal	$0{\cdot}15\ C^2$ lb. a fm.
Coir	$0{\cdot}11\ C^2$ lb. a fm.

4. *Care of ropes.*—The following precautions should be observed when working with cordage :—

i. To uncoil a rope; lay the coil flat with the inside end at the bottom, and uncoil by pulling the inside end up through the centre of the coil.

ii. Sudden or snapping stresses should be avoided.
iii. Cordage should be kept from chafing against sharp edges by interposing wood packing or rollers.
iv. Cordage, unavoidably exposed to chafing, should be "parcelled" by wrapping it in canvas well daubed with tar and bound with spun yarn.
v. Cordage that has been thoroughly saturated should not be subjected to a stress greater than two-thirds of its normal working stress.
vi. Cordage should never be returned to store wet, or coiled down in a wet condition.
vii. Cordage shrinks when wet; this shrinkage may cause guys, etc., to snap unless they are slackened off in wet weather.

5. *Strength.*—Manila ropes have been standardized as follows :—

Grade	Quality	Identification mark for 2-in. cordage and above
I	Special	A black yarn in three of the strands of the rope.
II	Standard	A black yarn in two of the strands of the rope.
III	Merchant	A black yarn in one of the strands of the rope.

The British standard breaking strengths for the common sizes of manila ropes and the approximate breaking strengths for other fibre ropes are given in Military Engineering, Vol. III, Part I. A factor of safety of 6 should normally be allowed and in any case more than one third of the ultimate load should never be put on a rope.

For work in the field it may be assumed that the strength of all types of cordage with the exception of coir is equal to C^2 cwt. where $C =$ the circumference of the rope in inches. This may be increased for good cordage in sound condition up to a maximum of $2C^2$ cwt. for "special" quality manila rope in first class condition. The safe load on coir may be taken as $\frac{C^2}{4}$ cwt.

The strength of cordage when taken round any sharp bend, such as the hook of a block, or when tied in a knot, is decreased by about one-third, owing to the fibres being unevenly stressed.

The safe calculated load for a piece of cordage must, therefore, be multiplied by two-thirds if there are any sharp bends.

A further allowance must be made when calculating the strength of a lashing to allow for the uneven distribution of stress between the turns; the actual strength should be taken as four-fifths of the calculated strength. It will normally be necessary to make these two allowances in conjunction. For example, the strength of a lashing of 4 turns (8 returns) of 2-inch cordage, securing a block to a spar

$$= 8 \times \frac{4}{5} \times \frac{2}{3} \times 4 = 17{\cdot}1 \text{ cwt.}$$

53. Knots and lashings

1. *Knots* are used to join two ropes, to form a loop in a rope or to make a stop on a rope as follows :—

Thumb knot (Plate **72**, Fig. 1). To make a stop on a rope, to prevent the end from fraying, or to prevent it slipping through a block.

Figure of 8 *knot* (Plate **72**, Fig. 2). As for a thumb knot, but easier to untie.

Reef knot (Plate **72**, Fig. 3). To *bend* or join two dry ropes of the same size.

Single-sheet bend (Plate **72**, Fig. 4). To join two dry ropes of different sizes.

Double-sheet bend (Plate **72**, Fig. 5). To join two ropes with great security, or two wet ropes of different sizes.

Hawser bend (Plate **72**, Fig. 6). To join large cables.

Running knot (Plate **73**, Fig. 6). To form a loop that will draw taut round an object.

Bowline (Plate **72**, Figs. 7, 8 and 9). To form a loop or *bight* on a rope that will not slip.

Running bowline. A bowline in which the standing end passes through the loop of the bowline.

Bowline on a bight (Plate **73**, Fig. 7). To form a double loop in the middle of a rope—made with the rope doubled.

2. *Hitches* are used to secure the ends of ropes to spars, to the hooks of blocks, to another rope, etc., as follows :—

Clove hitch (Plate **73**, Figs. 1 and 2). Consists of two half-hitches. Used to secure the end of a rope to a spar, etc.

Timber hitch (Plate **72**, Fig. 9). For holding timber, etc., where the weight will keep the hitch taut.

Two half-hitches (Plate **73**, Fig. 3). For making fast the running end of a rope on to its standing part.

Round turn and two half-hitches (Plate **73**, Fig. 4). For making fast a rope so that the strain on the rope shall not jam the hitches. Used for making fast a rope to a bollard or anchorage. If the running end is inconveniently long, a bight should be used to form the half-hitches.

Fishermen's bend (Plate **73**, Fig. 5). For making fast when there is a give-and-take motion, *e.g.* for bending a cable to an anchor.

Lever hitch (Plate **73**, Fig. 8). For fixing the rounds of a rope ladder, fixing bars to drag ropes, withdrawing pickets, etc.

Man harness hitch (Plate **73**, Fig. 9). To form a loop on a drag-rope that will not draw tight.

Catspaw (Plate **74**, Fig. 1). To secure the centre of a rope to a hook.

Single blackwall hitch (Plate **74**, Fig. 2). To secure the end of a rope to a hook.

Double blackwall hitch (Plate **74**, Fig. 3). More secure than a single blackwall hitch.

Draw hitch (Plate **74**, Fig. 4). To secure a boat's painter, etc., to a post, ring or rope so that it can be instantly released, or to secure horses to an endless rope when swimming them across a river. This hitch will stand a give-and-take motion, and can be instantly released by a jerk on the running end.

Stopper hitch (Plate **74**, Fig. 5). To transfer the strain from one rope to another.

Magnus hitch (Plate **75**, Figs. 1 and 2). To make fast to round spars when much friction is necessary to prevent slipping. More secure than clove hitch.

Rolling hitch (Plate **75**, Fig. 3). To make fast a rope end round an object or secure a rope to a hook, when a very secure fastening is required.

3. i. *Lashings* are used to join one object to another, such as a spar to a spar or a block to a spar. Cordage lashings soon become loose and require frequent adjustment. When possible, wire should be used. If no staples are available, the wire should be finished off round a set of returns and jammed between them and the timber; otherwise wire lashings should be made in a similar manner to cordage lashings.

Wooden wedges with well-blunted points should be used to tighten lashings; they should be driven in at the top of the lashing.

Frapping turns are turns of a lashing taken round other turns of the same lashing in order to make them tight.

ii. To *whip* a rope is to tie a piece of twine round the end to prevent it untwisting and fraying.

iii. A *square lashing* (Plate **75**, Fig. 6) is used to lash one spar at right angles to another.

To make a square lashing, begin with a clove hitch on one spar as explained in Plate **75**, twist the ends together; carry at least 4 turns round the spars as shown in the figure, keeping outside previous turns on one spar and inside on the other; take two or more frapping turns, beating in the corners of the lashings during the process; finish off with two half-hitches round the most convenient spar. For each complete turn of the lashing, there are 4 returns.

The clove hitch should always be on the opposite side of the spar to that on which the weight will come, *e.g.* on the leg below the transom, and on the leg above the ledger of a lashed trestle.

iv. A *diagonal lashing* (Plate **75**, Fig. 7) is used to lash two spars together that tend to spring apart.

To make a diagonal lashing, begin with a timber hitch or running bowline round both spars and draw them together; take 3 or 4 turns across each fork; finish with frapping turns and two half-hitches. When the spars are not horizontal, the lashing should be finished off above the junction.

v. A *rack lashing* is used for fastening down ribbands at the edge of the roadway of bridges. It consists of a 6-ft. length of 2-in. rope with a pointed stick about 2 in. long at one end.

vi. To *lash a block to a spar* (Plate **75**, Fig. 4). Lay the back of the hook against the spar, take a clove hitch round the spar above the hook; take several turns round the hook and spar; finish off with two half-hitches round the spar under the shell of the block.

vii. To *mouse* the hook of a block (Plate **75**, Fig. 4), *i.e.* to close the mouth of the hook with spun yarn so that the sling eye, etc., must remain in the hook, begin with a clove hitch near the centre of the spunyarn on the back of the hook; take several turns across the mouth of the hook; finish with one or two frapping turns, both ends starting from the back of the hook, and a reef knot.

viii. To *seize* the end of a rope to the standing part with spun yarn, twine or string (Plate **72**, Fig. 6), in order to make the fastening secure, make a clove hitch round the standing part with the spun yarn near its centre; take each part round both ropes in opposite directions, leaving one end long enough to make two frapping turns between the ropes; tie the two ends with a reef knot.

ix. To *fish spars*, *i.e.* to strengthen them by lashing other spars parallel to them, lay the fishing spars against the one to be fished so as to take off as much strain and be in as close contact as possible; make fast the lashing or lashings, if necessary, by laying one end along the spars and taking the returns round this end; pass the lashing round and round all the spars; make fast the end by making the last four or five returns rather slack, passing the end backwards under them, tightening up the returns and hauling the slack through; tighten the lashings by driving in wedges.

Either one continuous lashing or several separate ones may be used.

4. *Splicing.*—Cordage is often united by splicing instead of knots, especially when required to run through blocks or used with eyes: the short splice, long splice, and eye splice are shown on Plate **76**.

i. *Short splice.*—To make a short splice (Figs. 1 and 2), the ends of the two ropes to be spliced are unlaid and the strands are married—that is, the strands of one rope placed between the strands of the other, and drawn taut. The strands of one rope may then be seized to the other rope, while the splicing of the other strands is proceeded with by passing each strand from right to left over and under alternate strands in the opposite rope, in a way similar to that described for the eye splice (*see* sub-para. iii), below). The strands of the other rope are then treated in the same way and the splice completed. Such splices have been found to be as strong as the rope.

ii. *Long splice.*—A long splice (Fig. 3) is used when it is required to join up two ropes in such a way that they can still be rove through the same size block as before. This is effected by splicing each pair of strands at an interval of 2 or 3 ft. from the other strands. Begin by unstranding the end of each rope for a length of 2 or 3 ft., according to the size of the rope (not less than seven times the circumference of the rope), and marry the two ends as described for the short splice, bringing the unstranded portions well against each other. Select a pair of strands (one from each rope) which come opposite to each other, and twist them loosely together so as to get them out of the way temporarily. Then begin unstranding one strand of one of the ropes, replacing it carefully by the corresponding strand of the other rope to 3 or 4 inches from its end. Twist these two ends together to get them out of the way also, and then unlay the remaining strand of the second rope and replace it by the remaining one of the first rope. Now untwist each of these last strands and divide them into two equal portions, one portion from each strand being cut off and the other two being tied in a thumb knot, so as to fill up the vacant space in the lay of the strands. These ends are then twice taken over one strand

and below the next on each side of the knot and then cut off, and the whole dressed down with the mallet or marline spike. The other strands are then spliced in the same manner, and the splice thus completed. It has been found from experiment that a long splice is from 5 to 40 per cent. weaker than the rope.

In making splices which have not to run through a block, the ends of the strands should not be cut off close to the rope, but ½ in. should be left projecting.

iii. *Eye splice.*—To make an eye splice (Figs. 4, 5, and 6), unstrand a length of the end of the rope about two and a half times its circumference, and then bend the end down to the standing part to form an eye of the required size, laying the middle strand on the top of the rope and forcing it from right to left under one of the strands of the standing part, having previously opened them with a marline spike. The left-hand strand is then forced from right to left over one strand, and under the next on the left. Having turned the rope round to the left, so as to bring the right-hand strand on the top of all, force it from right to left under the strand of the rope immediately on the right of the one the first or middle strand was passed under. Each strand of the end is now passed in succession between the strands of the standing part, no two contiguous strands being passed under the same strand, and taken alternately over and under the strands of the standing part. The strands are opened by means of a marline spike, at the same time twisting the rope in a direction opposite to its lay, thus causing the hole to keep open when the marline spike is withdrawn. The strands when through should be drawn taut. They should be worked in twice, then halved and worked in once, and then halved again and worked in to complete the splice. When the splice is complete, their ends are cut off and the splice is beaten down with a wooden mallet. An eye-splice is nearly as strong a fastening as a bend with seizings, and stronger than a clove hitch.

54. Wire ropes

1. *Description and uses.*—Wire rope is normally made of steel wire laid up in a similar manner to cordage. There is no standard length for a coil of wire rope, but it is usually issued in coils of 100 fathoms.

Several wires twisted together form a strand and several strands twisted together form a rope. A 6/7 rope denotes one of 6 strands of 7 wires.

Wire rope is stronger and less liable to stretch than cordage,

but it is less flexible and, therefore, more difficult to handle. For bridging work it should be used in preference to cordage, whenever the stresses involved would necessitate the use of cordage larger than 3-in., or if stretch under load would be disadvantageous.

Wire rope is difficult to grip, and if power has to be applied by hand, cordage tackles or falls on which the men can haul should be attached to the wire rope.

The *weight* varies with the construction of the rope, but may be taken as C^2 lb. a fathom, where C is the circumference of the rope in inches.

2. *Care of wire ropes.*—

i. *Uncoiling.*—Small ropes are generally made up in coils, and large ropes are wound on reels. A coil of wire rope should be mounted on some form of improvised reel before being unwound. The reel should be mounted horizontally on a bar through its centre, supported at either end on two pickets.

It is most important to avoid kinks while unwinding, as they are difficult to remove and always damage the rope. They cannot be removed by a straight pull. Bars should be lashed firmly on either side; the kink should then be gradually straightened by beating it with a mallet, at the same time twisting the rope by means of the bars to preserve its proper form.

ii. *Coiling.*—Wire rope should normally be coiled on reels. If a reel or drum is not available, the rope should be coiled round pickets driven into the ground; the coil when complete should be secured at three or more points with spun-yarn, twine, etc. They should be coiled in a clockwise direction.

Large ropes should be coiled similarly with the use of pickets, but in the shape of a figure of eight.

iii. *Storage.*—Ropes should be stored under cover, and raised a few inches from the ground.

iv. *Avoidance of sharp bends.*—All sharp bends must be avoided (*see also* para. 3, below) and the rope should be protected from chafing.

As a rough rule, the diameter of a sheave should not be less than six times, or the diameter of a holdfast not less than four times, the circumference of the rope.

The correct size of sheave designed for the rope must always be used; otherwise excessive wear will result.

When under tension the turns on a holdfast or drum should never be allowed to override one another (for winch drums, *see* Sec. 59).

3. *Methods of joining and securing wire ropes.*—The following

methods may be used either to join two ropes, or to secure a rope to a load or holdfast :—

i. *Ordinary knots.*—In the field suitable wire rope fittings will not always be available. The ordinary cordage knots must then be used, but the following precautions must always be taken :—

(*a*) Very sharp turns must be avoided ; a round piece of wood, of a diameter not less than 4 times the circumference of the rope, should be inserted in the knot and the turns made round it (*see* Plate **77**, Fig. 1).

(*b*) The strands of the rope must be protected from being cut through by friction. Sacking should be inserted in the bights of knots and either sacking or sheet iron should be wrapped round a holdfast under the rope.

(*c*) The running end should be seized to the standing part of the rope.

Two ropes may be joined by a hawser bend as shown on Plate **77**, Fig. 1, two half-hitches being used.

ii. *Splicing.*—Wire ropes can also be joined together by splicing in a manner similar to that described for cordage. The figures on Plate **78** explain the operation of forming an eye splice, which is that most often required ; but the splicing of steel wire rope is very specialized work, and a rigger skilled in this work should, if possible, undertake it.

iii. *Thimbles* are normally heart-shaped. The rope is passed round the thimble and secured to itself either with an eye splice or with bull-dog clips or double-throated clamps (Plate **77**, Fig. 2). The first clip should be as close to the thimble as possible.

Thimbles should always be used when fastening a wire rope to the becket of a block, to a shackle or round the hook of a block.

iv. *Bull-dog clips* and *double-throated clamps* (*see* Plate **77**, Figs. 2 and 3) are the most convenient form of fastening for work in the field. The double-throated clamp is stronger than the bull-dog clip and damages the rope less ; it has four nuts and takes longer to secure, but should be used whenever possible. Double-throated clamps weaken the rope by about 5 per cent., whereas bull-dog clips weaken it by about 25 per cent.

The clips must fit the rope and it is essential that the correct size is used. They are marked with the size of the rope for which they are intended, some makers giving the diameter of the rope and others the circumference ; the diameters corresponding to the circumferences of the normal sizes of rope are given in Military Engineering, Vol. II, Part I.

Three clips should normally be used, but for ropes larger than 3-in., 4 or more may be necessary. If the rope is not fully stressed, two will be sufficient.

The distance between clips should be at least three times the width of the clip.

4. *The strength of a wire rope* depends on the size of the rope, on the breaking stress of the wire and on the construction. For the same size of rope, a variation of either of the last two factors may greatly alter the safe load for the rope.

Thus the safe load for a 6/12–2½ in.–80 tons a sq. in. rope is about 1¾ tons, while that for a 6/7–2½ in.–100 tons a sq. in. rope is about 3¾ tons. Any formula that merely takes into account the size of the rope must be regarded as very approximate.

The safe loads for the more common constructions of rope and strengths of wire can be found from Table 50 (p. 389).

The breaking strength of the common sizes of wire are given in Military Engineering, Vol. III, Part I, or may be found experimentally. The construction of the wire can be seen by inspection of the end of the rope. The factor of safety allowed is 6 ; for temporary work in the field this may be reduced to 4, provided the breaking strength of the wire is accurately known and that the rope is in good condition and fairly treated.

For hasty work in the field the safe load may be taken as from $9C^2$ cwt. for ordinary rope to $12\ C^2$ cwt. for good quality rope, where $C =$ the cirumference of the rope in inches.

As in the case of cordage, the safe calculated load must be multiplied by 2/3, if the rope is taken round any sharp bend.

An allowance, greater than in the case of cordage, is also necessary for uneven distribution of stress in the returns of a lashing, since S.W.R. is less pliable ; the actual strength should be taken as 3/5ths of the calculated strength.

For example, the safe strength of a lashing of 5 turns (10 returns) of 1½-in. S.W.R. is :—

$$10 \times 9 \times \frac{9}{4} \times \frac{2}{3} \times \frac{3}{5} = 81 \text{ cwt.}$$

5. *Wire rope construction in the field.*—A strand of 7 wires can be constructed by the method shown on Plate **79**.

The templet F should be made out of wood, preferably hard wood, about 1-in. thick and 1-ft. square ; for thick wires only very hard wood should be used with the holes, if possible, metal lined. The holes should be bored symmetrically in the form of a hexagon on a circle of about 8 in. in diameter with one hole in the centre for the core wire.

The *wires* should be attached at one end to pulley blocks G, passed through the template F and made fast to the block D. A picket E, 3 to 4 ft. long, should be passed through the wires close to the block to act as a twister.

The *pulley blocks* should be hooked into a single rope secured at either end to a picket and passing round 5 pulley blocks also secured to pickets so as to maintain an even strain on all the wires. The block for the core wire should be held by a man. The swivels of the pulley blocks should be well oiled so that the twist in each wire may be taken out.

To save the additional pulley blocks, the pulley blocks G may each be held by one man, spaced from 2 to 5 paces apart according to the length of the rope to be made. It is essential that the wires should be equally strained. The pulley blocks should be attached to a rope round the men's waists so that by leaning back a steady strain may be assured. The slackening of any wire during the process of twisting will at once produce unevenness in the strand.

The *spring balance* is required in order that an even tension may be maintained. Owing to the twisting of the wires except the core wire, the strand will be shorter than the original length of the wires. The straining tackle should be paid out gradually so that a tension of about 3 cwt. is maintained. The shortening amounts to about one per cent. If no spring balance is available, as even a tension as possible must be maintained.

To construct the strand two men twist on the twister and two others hold the template at right angles to the core wire. The template should be about 18 in. from the hook of block D at the start, and moved slowly backwards so as to remain that distance from the point where the wires come together as they twist. The template must not be allowed to twist even slightly; otherwise a faulty lay will result. The blocks should occasionally be given a turn to make sure that the friction of the swivel has not allowed the wire to twist; this is particularly necessary in the case of the core wire. When using wire of No. 8 gauge or thicker, the swivel blocks G will turn automatically.

A *rope* can be constructed by laying up several strands in a similar manner. Any number of wires or strands can be laid up together. The templet shown in Fig. 5 can be used to lay up three wires or strands using alternate holes and omitting the central hole. For a 19-wire or 37-wire strand a larger templet must be used as shown in Fig. 4. The holes should be bored for each layer in the form of a hexagon; the diameter of the circle on which the holes lie should be increased by about 8 in. for each successive layer. The practical difficulty of finding enough pulley blocks or of making a large enough template will usually preclude the laying up of more than 19 wires in one operation. Larger ropes should be made by laying up 3 or 7 strands together.

The *strength* of a strand may be taken as equal to the total strength of all the wires in the strand less the core wire, and the strength of a rope may be taken as equal to the total strength of all the strands in the rope less the core; for large ropes a fibre core may be used.

55. Miscellaneous fittings and attachments

1. In the field special fittings of the type described in this section will seldom be available in sufficient quantities, even if available at all, and it will, therefore, nearly always be necessary to improvise fastenings. On service, risks that might cause damage to the rope may often have to be taken, though not justified under peace conditions.

2. *Chains* are essential for certain classes of work, as in the case of heavy cranes where continual winding is done; wire rope, if used, would wear out quickly. For bridging work in the field its use is generally confined to short lengths for fastenings. The advantages are ease of handling and lack of stretch.

The different varieties of chain are :—

i. Short or close link chain, in which the length of a link is less than five times the diameter of iron in the link.

ii. Long link chain, in which the length of a link is at least five times the diameter of iron.

iii. Stud link chain.

The *weight* of chain varies from 59 to $64d^2$ lb. a fathom, where d = the diameter in inches of the iron.

Strength.—The breaking weight of a chain in tons is given by the formula :—

$$W = Kd^2,$$

Where d is the diameter of the iron in inches and K is a constant varying with the type of chain, as follows :—

Single weldless steel chain ...	47
Single stud link iron chain ...	36
Single short link iron chain ...	27
Single pitched iron chain ...	25
Single long link iron chain ...	21
Single twisted link iron chain ...	15

A factor of safety of 4 should be allowed for general use in the field, but for crane chains in continual use the factor of safety should be higher.

The following rough rule for calculating the strength of chains may be used :—

The safe load in tons =

$\frac{1}{10}$(number of eighths of an inch in the diameter of iron.)^2

This gives a factor of safety of about 3 for long link iron chain and of about 4 for short link iron chain.

3. *Slings* may be made of wire rope, cordage or chain. Where much lifting has to be done a selection of slings saves time in tying and untying knots. Slings should be adjusted so that the splice is not round any edges nor over the hook. They should not be left to adjust themselves, but should be so arranged that the stress will be equally divided between the returns. The sling should be protected from all sharp edges by sacking, etc. Slings in continuous use should be inspected at frequent intervals.

i. *Cordage slings* consist of a length of cordage with the two ends spliced together. They should be used for light work and for articles that would be damaged by a wire rope or chain bearing on them. The sling is passed round the article to be lifted, and the bight formed by one end is passed through the bight formed by the other and then over the hook of the lifting tackle.

ii. *Wire rope slings* are made and used in a similar manner to cordage slings, but for heavier loads. The rope is normally protected by spun yarn or some other whipping material wrapped round it. Double wire rope slings, *i.e.*, with two bights, are sometimes made ; they are convenient for lifting certain types of load.

iii. *Chain slings* are not as easy to handle or lap round the load as wire rope or cordage slings, but they are more durable ; they are heavier than wire slings of equal strength.

iv. *Slings with two or more legs* are often convenient. For example, large plates may be lifted by a four-legged sling, the hooks being passed through eyebolts inserted in suitable holes in the plate.

The angle between the legs of a sling should not exceed 60 degrees, since the stress in each leg increases rapidly as the legs are spread apart. The connection at the top of a chain or wire rope sling usually consists of a ring. The chain portion is connected to this by a long link, while a wire rope has a thimble spliced on in the usual manner. The connection at the lower end of the leg is similar, except that a hook takes the place of the ring.

v. *When calculating the strength of slings*, allowance must be made for the angle of the legs. If the angles between the legs are 60 degrees, the stress in each leg will be 1·15 times what it would be if they were parallel to the pull. The proportion becomes less as the angle decreases. Thus, if a 4-legged sling, in which each leg makes an angle of 30 degrees with the vertical, supports a load of 8 tons, the stress in each leg is :—

$$1{\cdot}15 \times \frac{8}{4} = 2{\cdot}30 \text{ tons.}$$

In short slings, provided the angle is not greater than 80 degrees, the pull in each arm may be taken as $\frac{2}{3}$W.

The rough formula given in para. 2, above, for calculating the strength of chains may also be used for rings and links, giving a factor of safety of about 3.

4. *Strops* (Plate **77**, Fig. 7) are lengths of wire rope with a thimble spliced in each end and with the rope itself wrapped with some material to protect it from damage.

They are very useful for attaching blocks of tackles to anchorages, and for forming the standing part of a guy.

The sizes of thimble used are not standardized, and the thimble at one end is often made small enough to pass through the thimble at the other end. In selecting strops, care must be taken that the thimble is large enough to take the hook of the block, etc., for which it is intended.

5. *Shackles* (Plate **80**) are extremely useful in all classes of heavy bridging work. Various types and patterns are made. The correct size as well as strength of shackle must be selected.

The strength of a shackle may be calculated by the rough formula for chains in para. 2, above ; the minimum diameter of the bolt should be taken, *i.e.*, the diameter at the bottom of the threads. This formula gives a factor of safety of about 3.

The safe load, allowing a factor of safety of about 4, is usually stamped on the shackle.

6. *Drag-ropes* are lengths of cordage with a hook spliced nto one end. There are two sizes in use in the service :—

i. 3-in. cordage, 5 fathoms long.

ii. 2-in. cordage, 15 ft. 6 in. long.

7. *Selvagees* (Plate **75**, Fig. 5) are used for slinging shells, but, when passed round an object, form a convenient means of attachment for the hooks of tackles. They should always be used double, and are only suitable when the strain to be taken is small.

56. Blocks and tackles

1. *Blocks* are used for the purpose of changing the direction of ropes and of gaining power at the expense of time. They consist of the following parts:—

- i. The *strap*, which holds the *pin* on which the *sheave* revolves, and to which a *shackle or hook* is attached at one end for carrying the weight and a *bucket* at its other end for attaching the fall.
- ii. The shell, the principal use of which is to prevent the rope slipping off the block.

The shell of all-metal blocks is usually made in one piece with the strap. The shell may be made of wood or metal, but wood blocks are seldom used in the service.

The sheaves of metal blocks are grooved and are made of malleable cast-iron or steel. The diameter of the sheave is dependent on the size of the rope to be used; if the sheave is too small, the strength of the rope, especially wire rope, is seriously diminished, and a proportion of the power is lost. On the other hand, the smaller the sheave the lighter the block. For wire ropes the diameter of the sheave should be at least six times the circumference of the rope.

Blocks are called single, double or treble according to the number of sheaves in the frame.

Snatch-blocks are single blocks with an opening in one side of the shell, so that a rope can be inserted without passing the end through. This opening is closed by a hinged strap.

As a rule, either the safe load or the test load is stamped on the block.

2. *Tackles* are composed of one or more blocks rove with a rope or fall. Those most commonly used are shown in Table 49.

The *fall* is the term used for the rope connecting the blocks.

Reeving is the operation of passing the fall round the sheaves of the blocks.

The *standing end* is the end of the fall made fast to one of the blocks. Blocks are fitted with a *becket* or eye to which the fall should be attached.

The *running end* is the loose end of the fall to which the power is applied.

The *returns* are the parts of the fall between the blocks.

To *overhaul* a tackle is to separate the blocks. With heavy tackles, the block from which the running end comes off, should be secured to a holdfast and a handspike should be placed in the hook of the other block with a drag-rope made fast to it; the handspike and drag-rope should be manned, while one or two men overhaul the returns from the standing block. The handspike is intended to keep the tackle out of the dirt which would otherwise clog the sheaves.

To *round in* a tackle is to bring the blocks closer together. With heavy tackles the reverse process to that for overhauling should be employed, the men on the handspike and drag-rope hanging back while a few men heave on the running end.

When the blocks are as close as they will go they are said to be *choc-a-bloc*.

To *rack* a tackle, any two opposite returns should be fastened together with a seizing so that the blocks will retain their relative position even if the running end is let go.

A *lifting tackle* is one in which the running end of the fall comes off the fixed block; it is normally used vertically.

A *runner tackle* is one in which the running end of the fall comes off the movable block; it is normally used horizontally.

A *leading block* is used to change the direction of the running end in order that the power may be favourably applied; as a rule, leading blocks are required for lifting tackles and not for runner tackles. They should be made fast to a holdfast close to the ground placed so as to give a good lead to the fall which runs through it. Snatch-blocks are normally used.

The *power* is applied to the running end by a winch or capstan, or by men pulling directly on the fall. Men cannot grip wire rope sufficiently well to apply power equal to the strength of the rope.

3. *Reeving a tackle.*—A tackle is rove by two men standing back to back, 6 ft. apart. The blocks are placed on their sides between the men's feet, hooks to their front, and the coil of rope to the right of that block at which there are to be the greater number of returns. Beginning with the lowest sheave of this block, the end of the fall which is to be the standing end is passed successively through the sheaves from right to left and then made fast to the becket with two half-hitches and seizing. The half-hitches should be as close up as possible, and very little spare end left for seizing, so that the blocks may not become choc-a-block unnecessarily soon.

All tackles should be rove in this manner, except that in the case of long heavy tackles it is better to reeve the blocks the working distance apart, to save overhauling after reeving.

Care must be taken to prevent mud and grit getting into the sheaves.

4. *Anti-twisters.*—All tackles are liable to twist when the

power is applied This is due to the lay of the rope and not to the method of reeving the tackle ; no method of reeving so that the running end comes off the centre sheave will make any practical difference to the tendency to twist. The longer the tackle the greater the liability to twist.

New ropes are more liable to twist than old ones. They should be well stretched before use by making one end fast to a swivel and applying power to the other ; the rope can then unlay as it is tautened.

The running end of the fall must be taken off so that it does not press against the shell or twist the blocks.

If the tackle is allowed to twist one complete turn, the power required is increased by over 40 per cent.

In all cases in which the tackle cannot be reached by hand after erection, anti-twisters must be secured before erection to the block that will be out of reach.

The most suitable type of anti-twister at a moving block consists of a maul with the helve passed through the loop of the first half hitch of the standing end on the becket, and projecting at least 6 in. above the returns of the tackle. It should be *firmly* secured with spun yarn as follows (Plate **81**, Fig. 1) :

> Make a split clove hitch round the head of the maul ; pass the double end of the spun yarn up the helve and secure it to the helve with two half hitches ; take a round turn through the becket and one turn of a square lashing with the double spun yarn round the helve and the loop of the standing end.

The tackle is prevented from twisting by the suspended weight of the maul. In long tackles, or if the head of the maul is too light, an additional weight must be secured to the bottom of the maul.

A crowbar may be used in place of a maul ; it should be secured in a similar manner, except that no split clove hitch can be used (Plate **81**, Fig. 2).

A light piece of wood, such as a picket or handspike, similarly secured, but passed half-way through the loop, may be used ; light lashings should be attached as reins to either end and secured in such a way that they cannot slip off (Plate **81**, Fig. 3).

5. *Care in handling tackles.*

i. The blocks should be well oiled and free from grit and dirt. No block in good working order should " complain," that is, make a noise.

ii. Care must be taken that all fastenings are secure.

iii. The fall must be free from kinks and twists, and must run freely over the sheaves.

iv. Tackles should be carried and not dragged along the ground.

v. When the fall is taut, it should not be jarred by being struck or by men treading on it.

vi. The returns near the blocks should not be touched when moving unless absolutely necessary, and then only those moving away from the block.

vii. A suspended weight should be eased off uniformly and not by jerks.

viii. In all cases when working near the safe limit of a tackle, before leaving it with the strain on, the tackle should be eased off slightly in order to distribute the stress equally between the returns.

ix. Men should be trained to pull together. The fall should be *double banked* in order to keep the pull in a straight line. On the command **" Taut "** the slack should be hauled in, and on the command **" Heave "** the men should heave together and hold what they get.

6. *Advantage gained by tackles.*—In any two-block tackle, if there were no loss of energy, the power necessary to overcome a force would be that force divided by the number of returns of the fall at the movable block, including the standing end of the fall if made fast to that block. In practice the loss of energy may seriously diminish this theoretical mechanical advantage ; this loss may be due to :—

i. The friction of the parts of the rope against each other or against the shell of the block. The loss from this cause may vary from nothing up to any amount, as it is possible if the tackle is twisted sufficiently to stop all movement. But by keeping the returns parallel and preventing the blocks from twisting, the loss may be kept down to a small quantity.

ii. The friction between the sheaves and the pin. If the blocks are kept clean and well lubricated, the loss due to this cause will be very small.

iii. The power required to bend the fall round the sheave. The loss of energy due to this cause depends on the stiffness of the rope and is therefore greater with wire rope than with cordage and with tarred cordage than with white.

To allow for the loss of energy due to all causes, the following formula should be used :—

$$P = \frac{W}{G}(1 + fn)$$

Where P = the power required on the running end of the fall.

W = the weight being moved, in the same units as P.

G = the theoretical advantage, or number of returns at the movable block.

n = the total number of sheaves, including any leading blocks.

f is a coefficient, varying from 1/5 to 1/10, according to the condition of the tackle. But provided the tackles are kept in good condition and that there are no riding returns, it may be taken as 1/10.

The pull on the beam or anchorage to which the fixed block is secured is :—

For lifting tackles ... ... W + P
For runner tackles... ... W − P

Values of W for cordage at C^2 and $2C^2$ cwt. and for S.W.R. at $9C^2$ and $12C^2$ cwt. are given in Table 49, page 386 *et seq.*

If the tackles are fully stressed, the value of P is, in each case, equal to the safe strength of the rope, *see* Secs. **52** and **54**, but if the tackle is not being used to its maximum capacity, the rope is not fully stressed, and the value of P must be calculated from the formula. The correct value of P will often be required in order to determine the type of winch or number of men necessary for the running end of the fall and also the correct values of W + P and W − P. An example of the method of determining the size of tackles required for guys, lifting tackles, etc., is given in Sec. **66**.

The leading block.—The load on the lashing of a leading block when the pull on the running end is P is $\sqrt{2}P = 1{\cdot}42P$, provided the angle between the ropes is approximately 90 degrees.

NOTE.—A summary of the formulae used in connection with ropes, tackles and rope fittings is given in Table 50, page 389, and an example is worked out in Chapter XIII.

CHAPTER XII

APPLICATION OF POWER AND ANCHORAGES

57. Man power

1. Experience is essential in the handling of heavy weights. A well-trained squad will move weights with half the exertion and in half the time taken by a less experienced squad.

Only by experience can men learn to know readily the best point to apply power, the amount of power to apply and the best method of applying it.

Men should not be allowed underneath any weight, of which there is the least danger of collapse, as in the case of a girder during launching or a trestle or derrick during erection.

2. *Man power constants.*—When estimating the number of men required to lift or move a weight, the following constants may be used as a guide :—

In squads of up to thirty men, each man can :—

i. Exert a horizontal pull of from 56 to 90 lb.
ii. Carry from 56 to 90 lb. when carrying a weight such as a spar, box girder section or a pontoon.
iii. Apply a tractive force of from 40 to 50 lb., *e.g.* on a drag-rope.
iv. Exert a continuous pressure of from 15 to 20 lb. on the handle of a capstan, winch, etc.

In parties of up to four men, each man can for short periods only :—

v. Push horizontally with a force of 100 lb.
vi. Lift 150 lb.
vii. Carry on the shoulders 120 lb.

The above figures apply only if the surface of the ground is reasonably good, and if the weights are such that each man can apply his full power.

3. *Parbuckling* is the simplest method of raising such weights as a timber baulk on to a trestle pier, abutment, etc., when no derrick is available.

For example, to raise a baulk on to the top of a double-bent trestle pier, make fast the ends of two lashings to stringers at either end of one of the capsills, and pass them down under the baulk and up to the top of the pier again. Haul equally on the two lashings, thus bringing up the baulk, turning over and over as it comes up. A turn should be taken round the far capsills with the free ends of the lashings so as to hold the weight between pulls. The baulk may be brought up on ways, but these are only necessary if there are projections on the pier that would otherwise interfere with the baulk as it comes up.

4. In *carrying a spar*, the party should be equally divided on either side of it and sized. The spar should be lifted in two motions on to the inner shoulders of the men. When lowering the men should face inwards slowly, and lower first the butt end and afterwards the tip. Separate words of command should be given for each movement.

58. Jacks

1. Jacks are either lifting jacks designed solely to raise the weight, or lifting and traversing jacks designed to traverse the weight sideways in addition to raising it.

There are two types in general use :—

i. Screw jacks.
ii. Hydraulic jacks.

2. *Screw jacks* have a vertical screw worked by a ratchet and lever. They are reliable but slow in operation. The types used in the service are designed for 6, 12, 15 and 20 ton loads.

3. *Hydraulic jacks* are worked by oil pressure by means of a small hand lever. They are handy, portable, easy to work and rapid in operation, but are liable to get out of order and need careful attention. In frosty weather they should be emptied when not in use.

The types used in the service are designed for 7½, 15, 22½, 30, 50 and 100-ton loads.

4. *Sand jacks* (Plate **82,** Fig. 3) can be easily improvised. They are useful for lowering heavy weights, such as heavy bridge spans on to their seatings, but they cannot be used for raising weights.

They consist of hollow steel cylinders filled with dry sand. The weight is taken on a wooden plunger made to fit inside the cylinder with an all-round clearance of about $\frac{3}{16}$ in. The weight is lowered by releasing the sand from holes bored in the sides of the cylinder at the base. The holes vary from ½ to 2 in. in diameter and the rate of flow of the sand through them is controlled by wooden plugs.

A sand jack to take 40 tons can be made from a length of steel pipe, 8-in. long, 8-in. in diameter and ⅜-in. thick. The rate of lowering with four 1¼-in. holes is 1 in. a minute. An allowance of 1 in. for settlement on application of the load should be made.

5. *Care of jacks.*—

i. Jacks must be kept free from dirt or grit.
ii. Jacks must be placed vertically under the weight, and, when the toe is used, as close to the weight as possible. They may, however, be used to exert a thrust in other directions than the vertical.
iii. Jacks should be used in pairs, if available, but care must be taken to lift equally on each jack.
iv. The weight should be followed up with packing, which must be carefully arranged on a firm base.
v. The jack must be supported on a sound level footing.

59. Winches

1. *Power of winches.*—Winches (Plate **82,** Figs. 1 and 2) are classified according to the power that can be applied to the rope as it leaves the drum ; the usual sizes are 1, 2, 3 and 5-ton.

The drum, round which the turns of the rope are taken, is always horizontal. The power is applied to a handle at each end, and further mechanical advantage is gained by the power being transmitted through toothed wheels. Most winches have a high and low gear. The high gear should be used when ever possible in order to save time.

Winches must be kept well oiled and free from grit and dirt.

2. *Stability of winches.*—Winches are mounted on cast or wrought iron frames ; the base of these frames is provided with holes through which the winches should be bolted to timber bearers of sufficient length to prevent overturning. To calculate the length of timber bearers required, *see* Fig. 2 (p. 130).

Where W = the weight of the winch,
P = the stress in the rope in the same units as W,
L = the distance from the end of the timber runners to the centre of the winch,
and H = the height of the bottom of the drum above the timber runners.

Then $WL = PH$.

The weight of the winch is not usually stamped on it. As a rough guide, a 2-ton winch weighs about 15 cwt. and a 3-ton winch about 1 ton.

About 1 ft. 6 in. should be added to the calculated length L to provide a margin of safety. To reduce the length of timber, a counter-weight may be used on top of the timber runners on the opposite side of the winch to that from which the pull is coming.

The winch should be secured to the bearers by bolts or coach screws through the holes provided.

To prevent the bearers from sliding along the ground, they must either be buried or secured by pickets driven into the ground in front of them. If the bearers are not buried they should be braced together to prevent racking of the winch when the rope moves to one end of the drum.

3. *Control and handling of winches.*—A winch party should consist of a commander, who may also control the brake, two men on each handle and one man guiding the rope on to the drum. When necessary four men may be employed on each handle. For continuous work one or two reliefs on the handles must be provided.

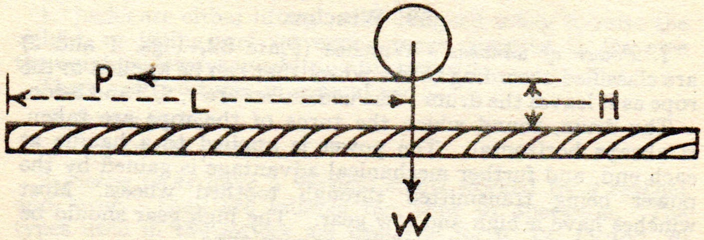


FIG. 2

The handles must always be manned, except that very light weights may be lowered on the brake provided it is done slowly, and that the handles of the winch are removed. The winch handles must never be allowed to revolve uncontrolled and must be secured with split pins or nails when in use.

The turns must be wound on to the drum closely and evenly. To facilitate this the winch must be placed at right angles to the pull, the rope being guided by a snatch block if necessary. In addition, owing to the movement of the rope from side to side of the drum, one man must always be employed guiding on the rope with a handspike. If spaces are left between the turns, succeeding layers of ropes will ride into these spaces and, if under load, will damage the lower layers to such an extent that the rope will be useless for further work. The rope should always come off the bottom of the drum.

Each winch should be allotted a number. Orders must be clear and distinct. The only words of command used should be :—

"Take in," "Pay out" and **"Stand fast."** On the command **"Stand fast"** being given the brake should be immediately applied and the pawl engaged. The commands **"Steady"** and **"Carry on"** should never be used. The commander of the winch is responsible that he is in a position to hear all orders, which he must acknowledge.

60. Miscellaneous gear for moving heavy weights

1. *Capstans* consist of a framework of wood or iron, supporting a vertical drum. They can be worked faster than a winch, but require more space and can only be used for comparatively small loads. The service crab capstan is shown on Plate **83,** Fig. 1.

The power is applied by horizontal capstan bars, generally two, passed through the head at right angles to each other.

The running end should be passed at least four times round the drum and should come off above the turns, the other end being attached to the weight to be moved. The running end must be held by two or more men. Sand or grit must not be put on the rope to make it grip.

The number of men on the bars varies with the power required. When additional power is necessary, the capstan bars may be *swifted,* that is, the ends of the bars lashed together with ropes for additional men to haul on.

In working up to the maximum stress there is a danger of splitting the capstan head.

A capstan may be improvised from a stout wheel laid upon its face on the ground with an axle put into it, fitted with a round piece of timber or capstan drum and bars to work it lashed across the head (Plate **83,** Fig. 2).

Capstans must be securely anchored to the ground.

2. A *Spanish windlass* is a form of improvised capstan. Two spars are arranged, one vertical and the other held horizontally against it (Plate **83,** Figs. 3 and 4). A rope is fastened to the weight to be moved and to an anchorage, the windlass being erected on the line of the rope and a bight of the rope taken round a horizontal spar.

The weight can be moved by walking round on the horizontal spar, the toe of the vertical spar moving towards the anchorage as the weight is pulled in.

No lashing is required, but care must be taken that :—

i. The rope on both sides, to the anchorage and to the weight, comes away from the vertical spar at the same level, preferably below the horizontal spar.

ii. The windlass is set up exactly in line with the weight and the anchorage.

iii. The vertical spar has a blunt end and the ground is hard; otherwise the spar will tend to bore a hole in the ground.

3. A *devil cart*, or lever cart (Plate **84**, Fig. 4), is very useful for raising and moving baulk timber and similar weights.

It consists of a pair of wheels, an axle and a pole secured to the centre of the axle, with its butt projecting from 1 to 2 in. to the rear and furnished with a hook.

The wheels are run over the centre of gravity of the log, and a rope or chain is passed under the log and hooked to the butt of the pole, which is lowered by raising the tip. The tip is then pulled down so as to raise the log, to which it is then lashed.

A devil cart can be improvised out of any strong pair of wheels with a good axle. The larger the wheels, the larger the size of the logs that can be dealt with.

4. *Rollers* may be either fixed or movable.

Fixed rollers consist of a solid cylinder of hard wood, cast iron or steel, mounted upon trunnions on a fixed frame. Special launching rollers of this type are provided with standard spans, suitable for the girders of the bridge.

Movable rollers are solid cylinders of hard wood, 5 to 12 in. in diameter. They are not suitable for launching girders, but are useful when moving heavy weights over fairly level ground.

Since the rollers communicate their own motion to the weight, the direction of a weight moving on rollers can be altered by changing the direction of the rollers under it. If the weight is to travel in a curve, the rollers must travel in the same curve, and must, therefore, be radial to the centre of that curve.

The weight travels twice as fast as the rollers.

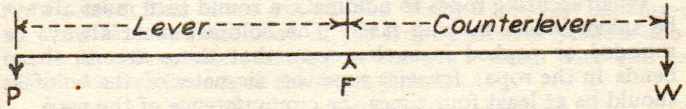
Rollers give no mechanical advantage, but substitute resistance to rolling in place of friction. The power required to move a weight on a level plank roadway on hard wood rollers varies from one-sixteenth of the weight to start it to one-twenty-fifth to keep it moving. On soft ground or uphill the power required is largely increased; lashings or projections on the weight offer considerable resistance to movement.

5. *Levers.*—A lever is a rigid bar capable of motion about a fixed point. The bar may be straight, as a handspike, or bent, as a claw hammer used to extract nails.

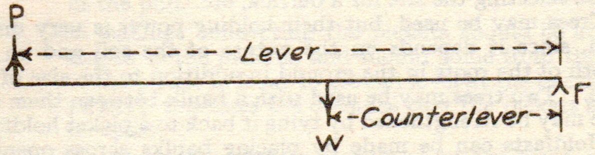
The point about which the lever turns is called the *fulcrum*. The distances from the fulcrum to the points of application of the power and weight are called the *lever* and *counterlever*, respectively.

A lever may be used in one of three ways :—

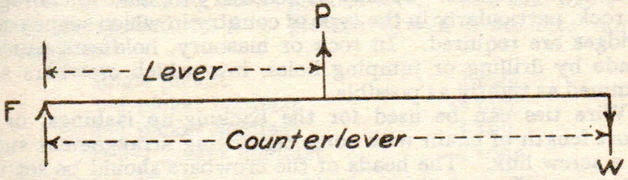
i. When the fulcrum is between the weight and the power, as in the case of the handle of a lift pump, thus :—



ii. When the weight is between the fulcrum and the power, as in the case of a wheelbarrow, thus :—



iii. When the power is between the fulcrum and the weight, as in the case of man raising a ladder or a spar; in this case the ladder or spar is the weight, the power is applied by the man, and the ground at the foot of the ladder is the fulcrum, thus :—



The power P required to raise a weight by lever is :—

$$P = \frac{W \times CL}{L}$$

where L is the length of the lever and CL is the length of the counterlever.

61. Anchorages

1. In nearly all bridging operations and in all operations that involve the raising of weights, fixed points are necessary to which ropes can be attached. These may consist of :—

- i. Anchors (*see* Chapter XIX).
- ii. Existing natural or structural holdfasts.
- iii. Picket holdfasts.
- iv. Combined picket and log holdfasts, known as baulk holdfasts.
- v. Rock holdfasts.
- vi. Buried anchorages.

When securing ropes to holdfasts, a round turn must always be taken before making fast. The holdfast must always be rounded or packed in such a way that there are no sharp bends in the rope; for wire rope the diameter of the holdfast should be at least four times the circumference of the rope.

2. *Existing holdfasts* should be used whenever possible and the possibility of their use should be taken into consideration when selecting the site for a derrick, etc.

Trees may be used, but their holding power is very uncertain, since it depends on the nature of the soil and on the depth of the roots in the ground in addition to the size of the tree. Two trees may be used with a baulk between them or a tree may be strengthened by tying it back to a picket holdfast.

Holdfasts can be made by placing baulks across openings in masonry; the stress should be distributed over a large surface by placing planks for the baulk to bear against. Slings round piers of arches may be used, but all corners should be protected by wood, or the rope itself parcelled to prevent chafing or cutting.

3. *Rock holdfasts.*—It may be necessary to make anchorages in rock, particularly in the type of country in which suspension bridges are required. In rock or masonry, holdfasts can be made by drilling or jumping holes, into which crowbars are jammed as tightly as possible.

Wire ties can be used for the backing-up lashings, or a short length of chain with some tightening arrangement such as a screw link. The heads of the crowbars should be set up to prevent the ties slipping off, if the bars bend.

In sound rock, the leading bar should be about the same diameter as an iron rope strong enough for the given stress.

4. *Picket holdfasts.*—Pickets may be used for pulls not exceeding 2 tons in ordinary soil. The pickets may be improvised, but the service pattern known as *park pickets,* are more convenient. They are made of ash, shod with an iron point, hooped with iron at the top to prevent splitting, and provided with an eye at the top. They are either 2 ft. 6 in. or 5 ft. long.

The pickets may be used singly or in groups of either: 1–1, 2–1, or 3–2–1 (Plate **84**, Fig. 1), connected by cordage lashings.

The lashing should be made as follows:—

Begin with a clove hitch on the head of the front picket or pickets below the eye; marry the ends of the rope for a length sufficient to pass round the backing-up picket; take four turns round the bottom of the backing-up picket and the head of the front picket or pickets above the clove hitch and below the eye; finish with two half hitches in rear of the front picket.

When constructing picket holdfasts, the following points should be observed:—

- i. The pickets should be driven at right angles to the line of the pull.
- ii. The lashings connecting the pickets should be at right angles to the pickets, and should come from the head of the picket in front to ground level at the backing-up picket; this fixes the distance that the pickets should be apart.
- iii. The eyes of the pickets should be to the front, except in the case of the rear picket of the group of three pickets.
- iv. The pickets should be driven at least two-thirds of their length into the ground.

In soft ground a picket will fail by pulling out, but in hard ground by breaking off at ground level. The safe loads that may be applied to 5-ft. pickets driven 3 ft. into normal ground are:—

single picket	7 cwt.
1–1 picket holdfast	14 cwt.
2–1 picket holdfast	1 ton.
3–2–1 picket holdfast	2 tons.

The factor of safety allowed is about two for pulling out of the ground and about three for breaking of the picket. The picket holdfast is normally the weakest part of any guy, etc. and should be carefully watched throughout the operation, since it will give an early indication of any excessive stress in the guy.

Failure by pulling out normally occurs gradually, but breaking of the picket is liable to occur suddenly.

In driving pickets of different sizes, the strongest should be nearest the weight.

Drawing pickets.—When drawing pickets and crowbars, care should be taken that they are drawn out in the same line as they were driven ; otherwise they are apt to break. Heavy pickets may be drawn with a light gyn or with a lever cart or with jacks. Park pickets should be drawn by means of a lever as follows :—

> Pass a clove hitch on a soft rope, or preferably on a chain if available, round the picket or pickets and draw it tight ; place a fulcrum such as a maul head in rear of the pickets ; insert the end of a stout lever under the knot of the clove hitch, place the ends of the rope or chain crossed between the fulcrum and the lever and bear down on the lever.

Another, and better, method, when no chain is available, is to put on a clove hitch in a rope round the picket and handspike ; draw up tight and twist the ends of the rope round the handspike tightly. Then place the tip of the handspike on a block of wood to act as a fulcrum and, gripping the ends of the rope against the handspike, lever upwards. Any suitable spar will do instead of a handspike.

Pickets should never be loosened by hitting them sideways with a maul.

5. *Baulk holdfasts.*—For pulls greater than 2 tons, and up to about 10 tons, a log may be used in conjunction with a series of 1–1 or 2–1 picket holdfasts (Plate **84**, Fig. 4) ; 3–2–1 picket holdfasts should not be used in combination with a log owing to the difficulty of driving the pickets so that each holdfast will take its fair proportion of the load.

In any combination of pickets and logs, it should be assumed that each picket can take a load of 6 cwt. ; this allows for a certain amount of uneven distribution of the pull.

When constructing baulk holdfasts, the following points should be observed :—

i. There should be the same number of holdfasts on either side of the rope.

ii. The holdfasts should not be less than 18 in. apart and and should be arranged symmetrically with respect to the rope.

iii. The log must bear as evenly as possible against all the pickets in the front row.

iv. The log should rest on the ground and should never be raised off the ground on packing. Sufficient soil must be removed to allow the rope to be passed round it.

v. The rear edge of logs of square section should be sunk in a shallow trench so as to give them a fair bearing on the pickets.

6. *Buried anchorages.*—For pulls in excess of about 10 tons, some form of buried anchorage must be used. For temporary work, this will normally take the form of a single log or group of logs buried horizontally, with or without the addition of sheeting to distribute the pressure (Plate **84**, Fig. **3**).

A trench should be dug about 2 ft. longer than the log with the face as nearly vertical as possible, and at right angles to the direction of the pull. Cable trenches from ground level to the bottom of the main trench at the correct slope for the cables must be made ; they should be as narrow as possible, and must be revetted where necessary.

The log should be lowered into the trench on to packing, by the use of ropes, the packing should be sufficient to raise the log high enough above the bottom of the trench to enable the cable to be passed round it ; light cables can be passed round the log before it is lowered. The earth should be filled in over the log and rammed, the cable trenches being kept open in order to allow of inspection of the cable and its fastenings. If the cable is likely to require adjustment, that part of the log where the cables are attached should be left uncovered, the earth being prevented from falling in by sandbag walls or some other form of revetment.

CHAPTER XIII

DERRICKS, SHEERS AND GYNS

62. Standing derricks

1. *Description and uses.*—A standing derrick, or derrick (Plate **85,** Fig. 2) is a single spar with the butt on the ground, and the tip held steady in the air by ropes or guys, of which it usually has four at right angles to each other in plan. It is used for raising weights where the radius of action required is small, and particularly for launching girders and for loading and unloading vehicles. The weight can be lifted and moved to the right or left and to the front or rear, but only to a limited distance.

The block of the lifting tackle should either be lashed to the spar, suspended by a sling passing through a slot in the head of the spar, or attached by shackles to a special headring. The fall passes through a leading block, which should be lashed to the derrick as near the ground as possible (Plate **85,** Fig. 3).

2. *Guys.*—Unless a special headring is used, the guys should be secured by clove hitches to the head of the derrick as nearly opposite one another and as near to the point of attachment of the lifting tackle as possible When long ropes are available the clove hitch may be in the centre, one rope thus acting as two guys.

The guys should normally be at a slope of 1 : 2, but in the case of buried holdfasts the slope should not be less than 1 : 3.

A *running guy* is one that has a tackle in it, which enables it to be adjusted. Running guys should be used for all guys on which the weight will come when the derrick is in use. It is an advantage to have running guys of steel wire rope, since this is less liable to stretch than cordage.

The length of ropes to be used in the tackles of guys must be *carefully* calculated in order to ensure that :—

i. The rope of the tackle is sufficiently long.
ii. The tackle will not become chock-a-block.

3. *Footropes* will always be necessary both during erection and while the derrick is in use. They may be single or double, splayed at 90°, according to the conditions of the site and to the directions of the heel of the derrick. Except for very light weights, 3-in. cordage heavy gyn tackles should be used. They should be attached as near to the point of rotation as possible so that the alteration in their length that must take place during raising or lowering may be reduced to a minimum.

The *footing* under the derrick must be firm and the butt should be sunk in a hole about 1-ft. deep. If the ground is too soft to withstand the pressure on the butt, properly constructed footings must be made to spread the load over a sufficiently large area of ground. These may consist either of timber baulks with cleats nailed to them to keep the butts in position, or of special base plates, similar to those supplied with the derrick for the large box girder bridge.

4. *Marking out the ground* (Plate **85,** Fig. 1)—

i. Choose a position C for the derrick foot and lay out a line FCB to mark the direction of the fore and back guys.
ii. Lay out a second line RCL at right angles to FCB to mark the side guys.
iii. Let CH represent the effective length of the spar. Measure distances CF, CR, CB and CL each equal to 2CH. Then provided the ground is flat, F, B, L and R represent the position of the holdfasts. If the ground slopes this must be allowed for so that the slope of the guys may be 1 : 2.

5. *Raising a derrick.*—Light derricks may be raised by hand, but heavier derricks must be raised with the help of a lever or a separate derrick. The methods of erection are as follows :—

i. *By hand.*—Lay the derrick in a line from the footing to one holdfast with the butt nearly over the footing. Secure a foot-rope to the butt and to a holdfast on the same side of the footing as the derrick and close to it. After the guys have been made fast to the tip of the derrick and to the holdfasts, raise the tip as high as possible by hand, supporting it after each lift on packing, or on a light timber frame which is moved gradually inwards. Haul in on the back guy, which should contain a runner tackle, and pay out on the fore guy until the derrick is in the required position. The side guys and foot-ropes must be adjusted as necessary while the derrick is being raised.

ii. *By moving lever* (Plate **85,** Fig. 3). Lay out the derrick as for raising by hand. Choose a light spar, about half the length of the derrick, as a lever, and place the butt close to the derrick and about a quarter of the length of the derrick from its base. Lash the lever to the guy by taking a number of turns round the tip of the lever and the guy and ending in a draw knot, the lashing being prevented from slipping down by a collar of rope ; a long loose end should be left so that the draw knot may be pulled out from the ground when the lever is raised. The lever must be provided with light side guys.

Raise the tip of the lever into the position shown in Fig. 2 by pulling on the back guy ; from this position further pulling on the back guy raises the derrick. When the lever is of no further use it will begin to rise off the ground, and should then be released from the guy by pulling the loose end of the lashing.

Alternatively, the lever may be secured to the guy by taking several turns of the guy round the lever ; when the lever is lifted off the ground, it may be detached by rolling it down the guy until the round turns come off ; this is only suitable for light weights, since there will be a jerk on the back guy as the lever is released.

iii. *By fixed lever.*—The position and size of the lever are the same as for the moving lever method, but the lever when erected remains vertical throughout the operation of raising the derrick. A split back guy must be used, consisting of a wire rope passing from the holdfast over the top of the lever, round a snatch-block at the head of the derrick and back to a cordage tackle secured to the holdfast. The lever should be guyed in all directions and a loose spare side guy provided to take the place of the first side guy when the derrick begins to foul it on the way up.

The top of the lever must be protected with hoop-iron, so that the wire will not cut into it. The wire rope must be kept in position on the lever either by spikes driven into the top of the lever or by pick-helves lashed to the top.

The fixed lever method is the most suitable for all heavy derricks.

iv. *By a separate derrick.*—A light derrick or sheers may first be erected to pick up the tip of the main derrick until the back guy can be brought into use.

6. *Walking a derrick.*—Derricks can be erected in one place and moved or *walked* to another. A short spar should be lashed at right angles to the derrick spar and about 2 ft. 6 in. from its base with a square lashing.

The guys are then slacked off, and the butt of the derrick can be moved by lifting on the short spar and at the same time levering the butt with a handspike. The butt must be controlled with foot-ropes.

7. *Limit of incline.*—Derricks should not be used at an incline greater than 3 : 1. When first loaded the incline should not exceed 5 : 1, since the guys will stretch under load.

This limit of incline fixes the distance at which a weight can be picked up.

8. *Lowering a derrick* may be effected in a similar manner to raising it, except that the process is reversed. Packing should be placed to support the head of the derrick when lowered. The foot-ropes must be taken in as the derrick comes down.

If the derrick is not very heavy, a plank may be used as a lever with one end butted against the foot of the derrick, and the other under the standing end of the guy. The plank should be nearly vertical.

63. Swinging derricks

1. *Description and uses.*—A swinging derrick is used where the radius of action provided by a standing derrick would be insufficient, and particularly for unloading stores from boats and barges (Plate **86**).

It consists of a standing derrick with a swinging arm, or *jib*, attached to it near its foot. The *main* or *lifting tackle* is attached to the tip of the jib, which is in turn attached to the head of the upright spar by a *connecting tackle*.

2. *Guys and struts.*—Since a swinging derrick will often be employed at the edge of a wharf where the use of a fore guy would be inconvenient, a strut or struts must be used instead. Normally two struts should be used, each about half as long again as the upright spar. The three spars should be lashed together as a gyn and erected so that the standing derrick is vertical and the two struts are at right angles in plan and situated symmetrically with respect to the edge of the wharf. Either two guys, one over each strut in plan, or three guys, one a back guy and the other two side guys set back at 20° from the edge of the wharf to allow room for the loads to be landed, may be used.

The guys should be similar to those employed for a standing derrick, but the stress in them is greater than in the guys of a standing derrick to deal with the same weight. They should always contain a tackle for purposes of adjustment, and to decrease stretch under load should preferably be of wire rope.

3. The *jib* should not be longer than the upright and is most conveniently formed of two spars, lashed together at

their tips. They should be lashed about 1 ft. or 18 in. from their butts to a stout cross-piece, which will bear against the butt of the upright (Plate **86**, Figs. 2 and 3).

The jib is supported preferably by a length of chain, secured at its centre by a clove hitch round the upright and prevented from descending by a collar of rope; each end is secured to one of the arms of the jib.

If only one spar is available, it should be fastened to the upright as shown on Plate **86**, Fig. 2.

4. *Control of the weight.*—The radius of action of the jib can be altered by taking in or paying out on the connecting tackle, and the weight can be raised or lowered by the main tackle.

The jib can be swung sideways by reins attached to its tip. It can only be swung right over the edge of the wharf on that side of the upright on which are the leading blocks of the connecting and main tackles. If it is necessary to swing both ways, duplicate leading blocks for the falls of these tackles must be provided.

The weight must be allowed to hang vertically from the tip of the jib. If it is hauled towards the butt of the upright, the thrust on the jib is increased, and if it is hauled away from the upright the stresses in the back guy and connecting tackle are increased. If the weight has to be brought in otherwise than by swinging to a flank, it should be done by raising the head of the jib by means of the connecting tackle.

64. Sheers

1. *Description and uses.*—Sheers consist of two spars with their butts apart on the ground and their tips lashed together and held steady in the air by a fore and back guy. For a given load the two spars are each lighter than the one required for a standing derrick; no side guys are necessary. Sheers can, therefore, often be employed where the use of a derrick would be impossible. On the other hand, they can only be used to move the weight in a straight line by swinging the load between the legs.

2. *Construction.*—The method of construction is as follows:—

i. Lay the two spars with their butts flush together on the ground and supported on a baulk near their tips.

ii. Make a clove hitch round one spar about 3 ft. from the tip, and take the rope loosely six or eight times round both spars above the clove hitch without riding.

iii. Take two frapping turns round the lashing (Plate **87**, Fig. 2), and make the end of the rope fast to the other spar by two half hitches just above the lashing.

iv. Open out the butts of the spars until their distance apart is about one-third of the length of the spars from butt to lashing. In the case of large spars the butts should be opened out to nearly the full distance before the lashing is fixed, as it will otherwise be too taut.

v. Lash on a ledger with square lashings near the butts so as to prevent them from splaying.

vi. Pass a sling over the fork, so that it will rest across the spars and not on the lashing between the spars.

vii. Hook the lifting tackle into the sling. If the tackle is heavy, it need not be hooked into the sling at first, but may be raised afterwards by means of a single block secured to the tip of one of the spars. The rope by which the tackle is raised should be fastened to the eye so that the hook will be free to be hooked into the two parts of the sling. Cleats should be nailed to one leg to enable a man to climb to the top.

3. The *guys* are similar to those required for a derrick. They should be made fast near the tips by clove hitches in such a way that they will draw the spars together when the stress comes on to them—that is, the fore guy to the rear spar and the back guy to the front spar (Plate **87**, Fig. 3).

When using sheers at the edge of a wharf or pier, the fore guy may be dispensed with, but the sheers must always have a distinct lean outwards.

4. *Foot-ropes* and *footings* will be required similar to those required for a derrick.

5. *Marking out the ground.*—Plate **87**, Fig. 1 represents, in plan, sheers laid out for erection on level ground.

AC and BC are the legs of the sheers (to the fork).
F is the fore guy holdfast.
R is the back guy holdfast.
M is the centre of the line AB at right angles to FR.
Make AC = BC and AB = $\frac{1}{2}$AC.
MF = MR = 2MC.

The fore and back guys and the holdfasts should be situated in the same vertical plane for working and raising.

6. *Walking sheers.*—Sheers may be *walked* in a similar manner to derricks.

7. The *limit of incline* is the same as for derricks, *i.e.* 3 : 1, with the same restriction to 5 : 1, when first loaded.

8. *Raising and lowering.*—Sheers may be raised and lowered in a similar manner to derricks, except that they are nearly always too heavy to be raised by hand.

65. Gyns

1. *Description and uses.*—A gyn consists of three spars lashed together at the tips, the butts forming an equilateral triangle on the ground. No guys are required, and the space occupied is small, but only a vertical lift is possible.

There are several varieties of service gyns, mostly intended for the lowering and raising of guns into and out of emplacements.

The lifting tackle is suspended from a sling passed over the crook formed by the tips of the spars.

2. *Construction.*—The method of constructing a gyn is as follows :—

i. Lay out the three spars with their butts flush and mark the point where the centre of the lashing will come about 3 ft. from the tip of the spars.

i. Leave the two outer spars where they are, rather more than their own diameter apart, and lay the third spar between them with its butt in the opposite direction, so that the marks on the three spars are in line. Support the tips of the spars on a baulk.

iii. Make a clove hitch on one of the outside spars and take the lashing over and under the three spars loosely six or eight times (Plate 87, Fig. 4). Take a couple of frapping turns round the lashing between each pair of spars in succession, and finish off with two half hitches on the other outside spar.

iv. Cross the two outer spars, or *cheeks*, until their butts are at a distance apart equal to about half the effective length of the spars.

v. Lash a ledger with square lashings across the cheeks about 1 ft. from the butts.

3. *Raising and lowering.*—The head should be lifted as far as possible by hand and the centre spar, or *prypole*, brought in towards the centre of the ledger already fixed, either by a handspike lashed across it or by a tackle. If the other end of the tackle is attached to the ledger, this must be allowed for in determining its diameter.

When the butts form an equilateral triangle, two more ledgers should be lashed across the butts of the legs.

If the lashing at the head has a tendency to slip down the legs of the gyn during erection, it can be prevented from doing so by a stout nail or spike driven temporarily into one of the legs.

To *lower* a gyn, the operation of raising is reversed.

4. *Practical points when working with gyns.*—

i. The feet should be on the same level and properly supported. They must be secured from slipping.

ii. The gyn should be placed with its head over the centre of gravity of the weight to be raised. If the weight has to be swung, the head should be symmetrical about the points of raising and lowering the weight.

iii. A suspended weight can be hauled straight towards the centre of the cheeks or towards the prypole without risk of upsetting the gyn, but hauling it to either flank or taking a swinging lift is liable to cause the gyn to capsize. The lower block should not be allowed to come outside the line joining the prypole and cheek. If there is a risk of the gyn capsizing, light side guys should be used.

iv. Light gyns can be carried horizontally for short distances. On good ground, a gyn may be hauled into position by drag ropes attached to the bottom of the spars. It should be moved with one of the apices of the triangle formed by the feet leading. It is easier to haul the cheeks to the prypole than to haul the prypole to the cheeks.

66. Calculations for derricks, sheers and gyns

(*See* Tables 47 to 50. Appendix IV, and Chapter XI.)

1. The following example of the calculations necessary for a standing derrick brings out all the points that have to be considered when designing such machines. Every case will have to be treated on its merits and this example, therefore, must only be taken as a guide.

Example.—Design a derrick to be used for unloading heavy packing cases from a railway truck on a siding on to lorries, which can back up near the trucks.

Weight of heaviest case	2 tons
Height of largest case	3 ft.
Height of bottom of truck from ground ...	3 ft. 6 in.
Height of bottom of lorry from ground ...	3 ft. 6 in.

2. *Length of spar required.*—

i. This will depend on the height from which the weight has to be picked up and the height to which it has to be raised, and in the case of derricks and sheers on the distance from the base at which the weight has to to be handled.

In this case, in order to get the tackle over the centre of the truck or lorry and allow working room it will be necessary to have the foot of the derrick about 3 ft. from the trucks and to heel over a total of 6 ft. As the maximum heel is $\frac{3}{1}$ the effective height to fulfil this requirement is 3 × 6 ft. = 18 ft. In any case of doubt draw a sketch.

ii. With the derrick heeled over and tackles nearly chock-a-block just picking up a case, the vertical height required between the point of attachment of tackles and the top of the case is :—

Height of floor of truck	3 ft. 6 in.
Height of tallest case	3 ft. 0 in.
Height of sling on weight say ...	3 ft. 0 in.
Allowance for chock-a-block	4 ft. 0 in.
Allowance for attachment to spar ...	1 ft. 0 in.
Working clearance	1 ft. 0 in.
Total ...	15 ft. 6 in.

An allowance must be made for the loss of vertical height due to the heel of the derrick. This may be taken as 1 in 20 for a heel of $\frac{3}{1}$. In this case, as the height is 15 ft. 6 in., this allowance will be less than 1 ft. Allow 1 ft. ; this makes a total of 16 ft. 6 in. Therefore, in this case (i) is the deciding factor and effective height must be 18 ft. The length of spar required will, then, be 18 ft. + 1 ft. in ground and 2 ft. spare at tip = 21 ft., of which 19 ft. will be actually under load.

3. *Size of spar.*—Max. load that can come on spar from Table 48 is 2W = 4 tons. (No allowance need be made for impact.)

Size of spar from table is 11-in. mean diameter.

Use 11-in. mean diameter spar 21-ft. long.

4. *Sling to weight.*—

Assume four-legged sling in which each leg makes an angle of 30 degrees with the vertical.

Then from Table 47 (p. 384), stress in each leg is

$$\frac{1{\cdot}15\text{W}}{4} = \frac{1{\cdot}15 \times 2}{4} = 0{\cdot}575 \text{ tons.} = 11{\cdot}5 \text{ cwt.}$$

Then $9\text{C}^2 = 11{\cdot}5.$

$\text{C}^2 = 1{\cdot}3$ (approx.)

Nearest size of S.W.R. is 1½ in.

Use 1½-in. S.W.R. sling double.

5. *Lifting tackle.*—

Weight to be lifted is 2 tons = 40 cwt. From Table 49 max. load that 3-in. heavy gyn cordage tackle can take is 31·8 cwt., therefore S.W.R. must be used. For convenience of handling it is best to use not less than a gun tackle (2/2). Size of rope required can be found from Table 49 or worked out as follows :—

$$\text{P} = \frac{\text{W}}{\text{G}}(1 + fn) \quad \text{Take } f \text{ as } \tfrac{1}{10}.$$

Then $\text{P} = \frac{40}{4}\left(1 + \frac{5}{10}\right)$ as there will be a leading block.

$= 15$ cwt.

Then $9\text{C}^2 = 15$ cwt.

$\text{C}^2 = 1{\cdot}57.$

Nearest S.W.R. is 1½ in.

Use 1½-in. S.W.R. gun tackle with a capstan or winch.

6. *Lashing for leading block.*—

Pull-in rope is 15 cwt.

Pull-in leading block lashing will be $\sqrt{2} \times 15$. (*See* Sec. 56.)

$$\sqrt{2} \times 15 = 1{\cdot}42 \times 15 = 21{\cdot}3 \text{ cwt.}$$

A lashing should never be bigger than 1½ in., owing to difficulty of making the lashing.

Try N turns of 1½-in. lashing. Strength of lashing is

$$2\text{N} \times 9 \times \frac{3}{2} \times \frac{3}{2} \times \frac{3}{5} \times \frac{2}{3},$$

allowing $\frac{3}{5}$ factor for uneven pull in a number of turns and $\frac{2}{3}$ factor for the sharp angle of the lashing.

This has to equal 21·3, so

$$N = \frac{21{\cdot}3 \times 2 \times 2 \times 5 \times 3}{2 \times 9 \times 3 \times 3 \times 3 \times 2} = \frac{106{\cdot}5}{81}$$

say 2 turns.

It is usual to put on four turns on all such lashings, and a smaller rope would have done, but 1½-in. is used in order to keep all S.W.R. the same size.

Use 4 turns 1½-in. S.W.R.

7. *Winch.*—

A 1-ton winch will be required.

Calculate winch bed from formula.

$WL = PH$ (*see* Sec. **59**).

where W = say 10 cwt.

P = 15 cwt.

H = say, 1 foot.

then $L = \frac{PH}{W} = \frac{15 \times 1}{10} = 1{\cdot}5$ ft.

Add, say, 2 ft. for stability, and allow 1 ft. 6 in. for fastening back portion of winch to runners, then length of runners required is 5 ft.

For a small winch use 3-in. runners.

For 3 ton and over use 4-in.

Use 3 *in. by* 5 *ft. runners.*

8. *Lashing block to spar.*—

Pull-in lashing is $W + P = 40 + 15 = 55$ cwt.

Use N turns of 1½-in. S.W.R.

Then strength is $2N \times 9 \times \frac{3}{2} \times \frac{3}{2} \times \frac{3}{5} \times \frac{2}{3}$ as before.

So $$N = \frac{55 \times 2 \times 2 \times 5 \times 3}{2 \times 9 \times 3 \times 3 \times 3 \times 2} = \frac{275}{81} = 3{\cdot}4.$$

So use four turns 1½-in. S.W.R.

9. *Guys.*—

Each guy may have to act as a back guy in turn, so make them all of equal strength.

Max. pull on back guy is $0{\cdot}7W = 0{\cdot}7 \times 40 = 28$ cwt.

Use a split guy of S.W.R. with a runner tackle in one side. A tackle is always advisable for ease of adjustment.

Pull-in each side is 14 cwt.

Then $$9C^2 = 14$$

$$C^2 = \frac{14}{9} = 1{\cdot}55$$

The guy must be 1½ in.

Tackle has to take 14 cwt.

From Table 48 a 3-in. gun tackle (W = SP) will take 1 ton.

Use 1½-in. split guy of S.W.R. with 3*-in. cordage gun tackle.*

10. *Anchorage.*—

Each anchorage has to take 14 cwt. so a 1/1 picket holdfast will do.

For safety use a 2/1 *in each side or a* 3 : 2 : 1 *for the two.*

11. *Sling to anchorage.*—

Try 1½-in. S.W.R. double. There are four returns each of strength $9C^2 = 20{\cdot}25$ cwt. This must be reduced by 2/3 to allow for the sharp turns on the hook of the block.

Strength is $4 \times 20{\cdot}25 \times \frac{2}{3} = \frac{162}{3} = 54$ cwt. which is amply strong, but will be used for convenience.

Use 1½-in. sling.

12. *Length of tackles.*—

It is most important to calculate the length of the tackles so that the correct length of cordage and S.W.R. may be rigged. If these are wrong the tackle may become chock-a-block, or foul the equalizing block before adjustment is complete. Calculate length required in the guy that is to be used for raising the derrick. Draw a diagram as in Plate **85,** Fig. 2. First draw the guy in its shortest position, *i.e.* when derrick is heeling back at 3/1. In the case of a split guy be careful to make AO = CO on the paper. In this position tackle should be nearly chock-a-block and will occupy, say 5 ft. Make allowance for sling, say 1 ft. Then the remainder of the guy will be S.W.R. Measure BOC. This will be the length of S.W.R. in the guy. Add a few feet for fastenings. Then draw position when derrick is just ready to be erected with the head on packing. Draw the S.W.R., B′O′C, the same length as before. Then AB′ will be the maximum length of the tackle. Multiply this by the number of returns in the tackle, five in this case, and add 20 ft. for hauling and the result gives the length of cordage required.

Notes.—1. It may turn out that the cordage required works out at more than 50 fathoms—the usual length of a fall. If a 113 fathom length is not available, a tackle can be put in each leg of the guy thus halving the required length of tackle.

2. In the case of guys with more than two returns of S.W.R., the tackle may foul the equalizing block at the top of the derrick. In this case the remedy is to put the holdfast for the cordage tackle further away.

3. In all cases the guy should be designed so that the cordage tackle is fully stressed and the number of returns in the S.W.R. will be governed by this factor.

A split guy has been designed in this case by way of illustration. A single guy would have done. A split guy is often convenient for other reasons.

4. The remaining guys do not need such long tackles, as they have only to adjust between the maximum heel angles. The tackles can be calculated in the same way.

13. *Foot-ropes.*—

Foot-ropes should be designed to take the same pull as the guy used in raising the derrick and should always have a tackle in them.

The method of calculation is given in Military Engineering, Vol. III, Part I. For heavy derricks two 3-in. cordage heavy gyn tackles are desirable. In this case a 3-in. cordage gun tackle would do, with a 3 : 2 : 1 holdfast.

67. Lashed trestle bridges

1. *Lashed trestles* are only suitable for temporary bridges for light loads. They can be rapidly constructed from trees cut close to the site and lashings of cordage or wire. No other materials are required.

A typical trestle, giving the names of the parts, is shown on Plate **88**, Fig. 2.

An accurate section of the gap should be made (*see* Sec. **50**), care being taken to allow for the depth of soft mud. The bridge should be given a camber of 1 in 30. (*See* Sec. **71,** 6.) When calculating the length of the legs, an allowance for the camber must be included.

The *ledger*, in rocks or boulders, should be high enough to clear any obstruction. If the bottom is soft, the ledger should be near the bottom of the leg. And if very soft, the legs should be prevented from sinking by flat shoes about 15 in. square of 1½ or 2-in. planking, spiked very accurately to the bottom of the legs.

2. *Placing trestles.*—If the water is not too deep, the trestles should be carried out and placed by hand. In deep water, they should be carried on to the bridge and lowered feet first down inclinded spars, called *ways* (Plate **88,** Fig. 1) ; the head should be controlled by spars lashed to the tips of the legs, afterwards used as handrails, and the feet by foot-ropes.

Alternatively, they may be taken out on a raft and tipped into position by means of guys.

3. *Longitudinal bracing.*—Each trestle must be separately braced on both sides of the bridge by struts driven into the bed of the river (Plate **88,** Fig. 1).

The trestles nearest to the bank must be securely strutted from the shore ; the struts should be lashed to pickets driven in on shore. They should be put on before the trestle is launched, and may be used to assist placing it in position. They must be secured before the first bay is used for placing the second trestle.

The struts for each trestle must be put on as the work progresses. When dismantling, they should only be removed as each trestle is removed ; otherwise the bridge may collapse in the direction of its length.

The roadbearers should be securely lashed to the transom; this increases the longitudinal stability of the bridge.

4. *Constructional details.*—

i. Begin work on the trestles by marking off the width of the roadway on the transom.

ii. The slope of the legs should be accurately 6/1. Lay out the legs at this slope from the points obtained in (i.)

iii. The ledger and transom should be laid out and lashed below the leg ; this facilitates launching.

iv. All joints should be secured by square lashings, except where the braces cross, when a diagonal lashing should be used. The frapping turns of the lashings must be made tight and well beaten in, with a drawing stroke in the direction in which they are put on. The lashings require constant attention.

v. The legs should first be lashed to the transom and ledger. The trestle must then be squared by making the diagonal braces equal before lashing them in position.

vi. The transom, ledger and the butt end of one of the braces should be on the same side of the legs, the other butt and the tips of the braces being on the opposite side ; this facilitates subsequent adjustment of the transom.

vii. The handrails should be lashed *inside* the legs ; this prevents a horse from getting his legs over the edge of the decking.

viii. Before allowing a load on to the bridge, each trestle in turn should be jumped in by as many men as possible crowding round it and jumping up and down together. The transoms should then be adjusted to the correct height.

CHAPTER XIV

METHODS OF LAUNCHING GIRDERS

68. Alternative methods

1. The *normal methods* of launching are :—

i. For short spans, by means of temporary bearers (*see* para. 2, below).

ii. For long spans, by the use of derricks and tackles (*see* Sec. **66**).

iii. Cantilever methods.

The problem of the military engineer is to make the available materials both for erection and construction of the bridge fit the gap with the least possible expenditure of time. It will often happen, therefore, that one of the following alternative methods of launching will be the most suitable :—

iv. Floating spans into position.

v. Erection of falsework.

Whatever the method chosen, it is essential that careful preparations are made before launching begins, to ensure that there will be no waste of time during launching. Careful inspection of the launching arrangements is of vital importance, particularly if derricks and tackles are used ; all tackles, slings, anchorages and their connections to one another must be examined.

2. *Temporary bearers*, either of timber or rails, may be used to span small gaps. The roadbearers are rolled out over the temporary bearers on wooden rollers or on piping, ropes or tackles being used to assist if necessary. R.S.Js. should be rolled across on the flat, and then up-ended.

If timber or rails of a suitable length are not available, roadbearers consisting of timber up to 10 in. by 10 in. or of light R.S.Js. up to about 14 ft. in length can be hauled up on to the far bridge seat with lashings. Above that length a light derrick, or one of the alternative methods described in the following paragraphs, should be used.

3. *The cantilever method* normally consists in building a tail on to the girder and adding a counterweight at the end of the tail sufficient to balance the weight of the girder ; the tail normally consists of spare sections of the girder. The girder is then pushed or pulled out on rollers until the head rests on the far bridge seat.

In order to reduce the length of the tail and the amount of counterweight required, a launching nose may be attached to the head of the girder.

The cantilever method can often be very conveniently employed when two or more bridges of the same type are being launched in a continuous string, *e.g.* several R.S.J. spans. The girders are connected together end to end on the near shore by fishplates or any other suitable means, and hauled across the gap, with tackles or winches if necessary, supported on rollers on the near bank seat and on each of the piers. The spans must be so arranged that the head of the first girder reaches each successive pier before the joint at the tail has left the previous pier.

This method can be adapted for launching light assault bridges over narrow gaps, such as canal locks. The bridge is built on a pair of wheels and a tail added as a counterweight ; it can then be pushed up to the gap and the bridge launched very rapidly.

4. *Floating spans into position.*—Launching may be effected by supporting the head of the girders or bridge on a pontoon or similar raft. This method is particularly suitable for water gaps, where the erection of a derrick is difficult, *e.g.* on an isolated pier in the middle of a river, provided there is sufficient water to float the raft and that the current is not excessive.

The girders are constructed on rollers on the shore in the normal way and pushed out until the head dips on to the raft.

The position of the raft will vary according to the conditions of the site, but the girders must project sufficiently far beyond the end of the raft to allow them to be brought easily into position over the far bridge seat. Launching is effected by pushing or hauling on the raft and girders simultaneously.

The weight of the girders to be borne by the raft must be carefully calculated and the girders must be supported accordingly on the raft at such a height that they will only just clear the far bridge seat, in order to reduce the work of lowering the girder into position to a minimum. There is no limit to the height of the packing or crib-work supporting the girder, provided the buoyancy of the raft is sufficient to take the load, and that the crib-work itself is stable.

The girders should be lowered into the final position by a combination of jacking up the girder while removing the raft and sinking the raft by loading it with men and filling it with water.

If the river is tidal, the fall of the tide may be used; in this case all the girders of the bridge should normally be launched simultaneously.

5. *Erection of falsework.*—For certain types of gap, especially shallow gaps, the simplest method of erection may be to build a temporary structure, termed falsework, on which the permanent bridge is built. The temporary structure may take the form of temporary piers over which the girders are launched by the cantilever method.

Tubular scaffolding is very suitable for use as falsework.

69. Launching by derrick and preventer tackle

1. *Description.*—This method of launching is illustrated in Manual of Military Engineering, Vol. III, Part II, Pamphlet No. 1 (1932), Plate 13, which shows the normal lay-out for the launching of a 96-ft. large box girder. The method consists essentially of a derrick and hauling tackle on the far bank, and launching rollers, upon which the span is supported, and a preventer tackle and anchorage on the near bank.

The derrick, the centre line of the rollers and the centre of the preventer anchorage should all lie in one vertical plane known as the launching plane. With a 2- or 3-girder bridge, the launching plane coincides with the centre line of the bridge; with a 4-girder bridge it coincides with the centre line of one of the inner girders.

The hauling tackle is attached to the head of the girder and to the head of the derrick, the running end being taken down the derrick and through a snatchblock to the hauling tackle winch, which may be in any convenient position.

The preventer tackle is attached to the tail of the girder and to the preventer tackle anchorage, the running end being taken to the preventer tackle winch, which should be as near as possible in the line of the girder, consistent with clearing the tackle.

The girder is launched by taking in on the hauling tackle and paying out on the preventer tackle. As soon as the centre of gravity of the girder passes the launching rollers the head of the girder should be given a dip equal to about one-tenth of the span; this assists launching and reduces the stresses in the hauling tackles. The rate of taking in and paying out should be such that the head of the girder remains at this dip, until the far bank is reached. Normally, the tackles should then be controlled so that the head of the girder just clears the bank as it comes up on to the bridge seat. In the case of the large box girder, however, special considerations apply (*see* Large Box Girder Pamphlet).

The near end of the girder is then jacked or levered off the launching rollers on to the bridge seat.

"*Delaunching*" is effected by paying out on the hauling tackle and taking in on the preventer tackle, the process of launching being exactly reversed.

2. *Practical details.*—

i. *Inspection of launching gear.*—Just before the girder is to be launched, or in the case of the derrick before its erection, the officer or N.C.O. in charge of the operations should inspect the launching gear to see that it agrees with the plan, that all fastenings have been correctly put on and are secure, especially bull-dog clips, and that tackles are rove to the correct lengths.

ii. *Getting stores across the gap.*—The derrick, guys, hauling tackle and timber for the far bank seat and anchorages have to be taken to the far side of the gap; the hauling tackle winch can be erected on the near bank provided the length of rope in the tackle is sufficient.

Before a bridge involving the use of heavy girders is required, there will usually be some other form of bridge across the obstacle. If there is no convenient bridge, in wet gaps the derrick and other timbers can be floated across, and the remaining stores taken across on a raft; in dry gaps, it will usually be possible to manhandle the stores across, but a light rope way (*see* Sec. **74, 5**) may have to be constructed.

iii. *Anchorages.*—Bridges involving the use of heavy girders will normally be constructed on the alignment of a previous bridge. With the normal launching gear lay-out, this would generally necessitate log anchorages in macadam or concrete roads.

The preventer tackle anchorage will be the most difficult problem. It may be necessary to split the attachment between the tackle and the anchorage, making two anchorages, one on either side of the road. In some cases it will be possible to make use of abutment arches, recesses in brick walls, manholes, etc. Where the road bends close to the bridge site, suitable ground for the anchorage may be obtained by lengthening the attachment between the tackle and the anchorage.

The back guy anchorage can be dealt with in a similar manner, but more easily, since the stresses involved are smaller.

The side guy anchorages may present difficulties. If the side guys are not at right angles to the launching plane, they will act to some extent as back guys, and must therefore be made strong enough to do so. It will sometimes be simplest to split the back guy at an angle of 45 degrees on either side of the launching plane, the split back guy being made to act also as side guys.

iv. *Preventer tackle winch.*—The direction of the pull of the running end of the preventer tackle should be as nearly as possible in the launching plane. If the winch has to be set to one side of this plane, the angle the running end makes with the drum will vary as launching proceeds. Since this angle should be as nearly as possible a right angle, it may be advisable to use a snatchblock to guide the running end at the correct angle on to the drum ; this snatchblock should be as nearly as possible in the line of the launching plane, but the winch may then be placed in any convenient position.

v. The *derrick* should be heeled slightly away from the gap before taking the load ; under load the back guy will stretch and the derrick should then be upright.

vi. *Hooking in the hauling tackle.*—The rope in the hauling tackle may not be long enough to allow of hooking in while the head of the girder is still on the near bank. The girder should be pushed forward by hand as far as possible, a counterweight being used if necessary. Provided the girder does not have to be pushed up a slope, and that the rollers are well-oiled and in good condition, girders weighing 50 tons or more can be moved by hand.

Turning winch handles is a slow process, and should be reduced to a minimum.

vii. *Lengthening preventer tackle rope.*—If the rope of the preventer tackle is found to be too short before launching is completed, a second rope can be joined on to it by first taking a few turns with it round the winch drum and then making it fast to the original rope with bull-dog clips in the normal way. Launching is continued and the second rope gradually takes the strain off the first. This expedient can only be used if the additional length required is so small that the join will not foul the moving block.

CHAPTER XV

BRIDGE TYPES

70. General description

1. *Types of bridge.*—A bridge may consist of either :—

i. A single span, spanning the whole gap ;
ii. Several spans, the junctions of which are supported on piers.

The *piers* may be floating piers, or fixed piers such as trestles, cribs, piles, etc.

Each *span*, or *bay*, between the piers consists of *superstructure* supported on *roadbearers*, which are supported at their ends on *bridge seats* or *transoms*.

2. The *superstructure* consists normally of :—

i. *Decking*, consisting of planks at right angles to the bridge.
ii. *Wheel-guides*, or *ribands*, which serve the double purpose of holding down the decking and of keeping the traffic on the bridge.
iii. A *footwalk*, on one or both sides of the bridge, to take foot traffic.
iv. *Handrails*, which should be strong enough to support the weight of men.

3. The *roadbearers* consist of any available material strong enough to take the load, the length of a bay normally being decided by the length and strength of the roadbearers available. They may be either :—

i. Steel girders, either of standard equipment or obtained locally.
ii. Rolled steel joists.
iii. Rails.
iv. Timber, square or round.
v. Timber girders.

4. The *bridge seats*, usually of timber, are secured on the top of the piers or abutments to support the roadbearers. Sometimes the roadbearers may rest directly on top of the *transom*,

i.e. the top member of a trestle. The bridge seat on shore is sometimes called the shore transom.

5. *Wheel-guides* should be made of the stoutest material available, either of timber not less than 6 in. by 6 in. in size, or of angle irons not less than 6 in. high ; but they must not exceed 9½ in. in height.

They must be securely fixed and should be bolted through the decking either to the main structure of the bridge or to parallel runners underneath the decking (*see* Plate **99**).

The wheel-guides must be splayed outwards at the ends of the bridge in order to ensure that vehicles use the central part of the bridge only.

6. *Footwalks*, either single or double, should always be provided.

The simplest design is that shown on Plate **99**, consisting of 1½ or 2-in. planking supported on extended decking pieces. The number of the latter depends on the strength of the planking used for the footwalks.

Suitable dimensions are shown on Plate **99**, but in any case the distance in the clear between the wheel-guide and handrail should not be less than 1 ft. 9 in.

7. *Handrails* should be provided on both sides of the roadway. They should be about 3 ft. above the roadway, and may consist of light spars, scantling, iron piping or cordage, fastened to uprights, fixed to points of support or other portions of the bridge.

They must be as strong as possible, and in any case must be strong enough to support the weight of a man. A suitable design is shown on Plate **98**. The uprights must be firm and either struts or gusset plates should be used.

On a bridge over a deep gap or rushing water, it is essential to fasten screens of canvas or brushwood to the handrails to prevent animals becoming frightened when crossing.

8. *Decking*.—A suitable size of decking should be selected from Military Engineering, Vol. III, Part I, 1934, Table XV, the size required depending on the spacing of the roadbearers and nature of the load.

Normally, 3-in. planks are suitable for medium loads, and 2-in. planks for light loads.

If the available planks are too weak, they may be strengthened by fixing a second layer of 1-in. or 2-in. planks either diagonally or longitudinally across the first layer. This has the further advantage that the top layer of planks can be easily replaced when it begins to wear.

A covering of matting, straw, or sand should be laid for horse traffic ; this will need constant attention.

The decking planks must be secured from movement. Though, as a temporary measure, the wheel-guides may be relied upon to fix the decking, they do not, as a rule, hold down the decking planks securely except in the immediate neighbourhood of the bolts, and the decking should be more securely fixed as soon as possible.

If the roadbearers are of timber, the decking can be secured direct to them with nails and spikes.

If they are of steel, one of the following methods must be adopted :—

i. Spike the decking to sole-bars, *i.e.* timber runners, which are either bolted to the top of the roadbearers or supported in some other way. This is the normal method.

ii. Nail battens on the underside of the planks.

iii. Secure the decking to the wheel-guides by bolts or spikes. This, however, leaves the whole superstructure free to move on the roadbearers.

71. Ruling dimensions

1. *Width of roadway*.—

i. *Infantry, cavalry and pack transport*.—The minimum width of roadway in the clear, *i.e.* between wheel-guides, should be :—

Infantry in single file	1 ft. 10 in.
Infantry in file	5 ft.
Cavalry in single file	
Pack transport	
Infantry in fours	9 ft.
Cavalry in half sections	

ii. *Vehicles*.—The normal width of roadway in the clear should not be less than 10 ft. for one way traffic. This should be increased to 11 ft. for large vehicles such as motor coaches and buses, and also if the approach on to the bridge is not straight.

Vehicles can cross a bridge even if the roadway is only a few inches wider than their wheel tracks, but at a greatly reduced speed. In an emergency, therefore, the width of roadway may be reduced, but this should only be done in exceptional cases.

The minimum width for two-way traffic is 18 ft.

In the case of several types of armoured fighting vehicles, drivers are unable to see the wheel-guides. Two guiding marks (one is not sufficient), at each end of the bridge must be erected in continuation of the centre line. These may take the form of lights by night, or of white posts or boards by day. Unless they can be erected on the ground, without obstructing the roadway, they should be hung above the roadway.

2. *Handrails.*—At least 9 in. clearance from the inside of the wheel-guide on either side should be allowed.

For loaded camels, the minimum width between handrails is 10 ft.

3. The *headway* of ordinary military bridges should not be less than 11 ft. 6 in. for medium bridges and not less than 13 ft. for heavy bridges.

4. The *waterway* to be allowed between fenders, headway above mean water-level, and the depth of water in navigable rivers depends on the type of river traffic. The necessary dimensions should be ascertained locally in each case.

Where the towpath cannot be continued at full width under the bridge, a footway at least 1 ft. 9 in. wide is required along both sides of the navigable opening to facilitate the passage of barges.

Provision may have to be made in floating bridges for a cut of prescribed width or, alternatively, for swinging bridge to pass water traffic.

5. *Railway clearance.*—The inside dimensions for a bridge over a railway vary not only between countries, but for each line within any one country. The requirements for each line should be ascertained locally.

6. *Camber.*—In order to allow for deflection when loaded the centre of a bridge should be made higher than the ends; this extra height is called camber.

The amount of camber allowed should be such that the bridge will be level when fully loaded, but it is better that the bridge should be arched rather than hollowed.

The amount will depend on the conditions, and may vary from 1 in 30 to 1 in 120. For timber girders, about 1 in 60 should be allowed. Suspension bridges should be given a camber of 1 in 30. In the case of a bridge with intermediate piers, extra camber may be required to compensate for settlement of the piers.

72. Short spans

1. R.S.Js. form the most satisfactory type of roadbearer for short spans. They will normally be available in limited quantities in engineer parks, and may often be obtainable locally. The dimensions and weights of the more common sizes are given in Tables 36 and 52.

R.S.Js. must be secured from overturning, particularly if tracked vehicles are to use the bridge. Timber distance pieces should be placed between pairs at each end of the span and bolts passed through the R.S.Js. and the timber. If possible, the necessary holes in the R.S.Js. should be made before they are sent to the site. Otherwise an oxy-acetylene plant or ratchet drills must be obtained. If the R.S.Js. are whippy, extra distance pieces should be fixed in the middle of the span.

The R.S.Js. should be secured by spikes from movement on the bridge seats.

The best method of fastening the decking is to bolt sole-bars along the top of the R.S.Js. and spike the decking to these. To avoid having to make holes for the bolts, the sole-bars may be supported on the distance pieces, but they must have sufficient points of support to prevent excessive deflection.

An example of the design of a R.S.J. span is shown on Plate **98.**

At the junction of two spans, the R.S.Js. should be made to overlap on the capsill of single bent piers. They may however, be allowed to butt on double bent piers, since there will usually be ample bearing area.

2. *Rail spans.*—Rails will nearly always be obtainable from local resources and form a very suitable means of bridging small gaps. Since they are whippy and liable to excessive deflection, their use should be confined to temporary structures.

Safe loads on certain rails are given in Table 52. For full details of rails, *see* Military Engineering, Vol. III, Part I.

The rails should be spiked to the capsills or bridge seats, chairs being used for flat-bottomed rails.

The decking should be nailed or spiked to two timber roadbearers, used in addition to the rails especially for this purpose. If suitable timber is not available, it will be sufficient to rely on the wheel-guides as a fixing for the decking as a temporary measure.

In relatively long spans, the rails should be bolted together in pairs to overcome whippiness.

3. *Timber spans.*—Timber forms the most suitable roadbearers for foot traffic, pack transport and light loads, and may also be used for medium and heavy loads over very short spans.

Timber planks should be used on edge in order to make use of their full strength. They must then be secured by distance pieces, etc., from overturning.

At the junction of two spans it will not usually be possible to overlap timber roadbearers, except for light loads, owing to their width.

The timber should be fixed with bolts, dogs or spikes.

Round timber should be adzed to give a level bearing.

73. Timber girder bridges

1. *Description and uses.*—For gaps up to 100 ft. in width, in which for any reason central supports cannot be constructed, girders of timber may be used. Such bridges are slow and laborious to construct and their use should be confined, as a rule, to cases where no other form of bridge is practicable.

They should never be used if suitable steel girders are available and can be transported to the site; for short spans, they may be used in preference to suspension bridges.

Timber girders may be constructed out of timber and steel rods, out of timber and sheet iron, or out of timber alone, and can be made to carry medium loads across spans up to about 100 ft. in length.

Deck bridges, in which the roadway is carried on the top boom should normally be used.

Several types of girder can be constructed, the choice depending mainly on the materials available.

Plates **89, 90** show light foot-bridges for infantry in single file. Similar bridges can be made of heavier material for medium loads.

Other types, suitable for field use, are shown on Plates **91** and **92.** The Pratt truss (Plate **91**) is the type most generally used.

The names of the members of the girder are shown on the plate.

Military Engineering, Vol. III, Part I, 1934, Table XIX, gives the sizes of the various members required for medium loads over spans of from 30 to 100 ft.

2. *Camber.*—The girders should be given a camber of 1 in 60 in order to allow for *taking up* in the joints under load.

In order to construct the girder to the required camber, the booms should be laid out with the various members breaking joint and conforming to the required curve as closely as possible. This is effected by cutting the ends of the members to a slight angle so that they butt well at this curve. They should then be bolted up in this position.

3. The *joints* used are similar to those used in roof trusses. They should be made as shown on Plates **91** and **92.**

Practical points in joint design :—

i. The centre lines of all members meeting at a joint should intersect in a point.

ii. Diagonals, if of steel rods, may either be single, in which case they pass through the centre of the booms, or double, passing between the members forming the booms, or outside the booms.

iii. A hardwood chock should be fixed to the boom in order to transmit the stress in the diagonal to the boom (*see* Plate **91**). With steel rods as diagonals, a plate or washer must be used.

The chock should either be let into the boom as shown on Plate **91,** or made longer and nailed or bound on top as on Plate **92.**

iv. If the booms are built up with a gap between the members, as on Plates **91** and **92,** the gap should be filled at the joints with packing and the whole bolted together to form a rigid joint.

v. Joints in booms should be as far from the centre of the the girder as possible, and should be made by bolting a cover-plate over the joint. This cover-plate is usually continuous over the whole length of the girder.

4. *Launching.*—Timber girders are launched in the same way as steel girders (*see* Chapter XIV) except that as the girders are much lighter tackles and gear may be much lighter and winches are not, as a rule, required.

The girders have little lateral strength and are liable to break during launching; they must be kept upright. It will often be advisable to launch them in pairs securely braced together. If launched separately, each girder must be temporarily strutted or tied during the launching of the remaining girders.

When all are launched, they must be securely cross-braced together.

74. Suspension bridges

1. *Description.*—A suspension bridge consists of a roadway supported by cables, usually two in number, passing over the top of piers to anchorages on either bank. The stability of the whole bridge depends on the anchorages, and the site should, therefore, be chosen with the banks of sound rock or earth.

Suspension bridges are the most rapidly constructed and most practical type of bridge for light loads for spans of 100 ft. and upwards, where the bottom of the gap to be bridged cannot be used on account of the depth of the chasm or the swiftness of the current. They are especially applicable to the conditions of warfare in mountainous or uncivilized country, where the general lack of communications necessitates the expedition being equipped with pack or coolie transport.

It will often be necessary for the approaches to be at right angles to the bridge ; the design must ensure that the cables from the top of the piers to the anchorages allow sufficient headroom for the traffic.

The common suspension bridge (Plate **93**) is described in the following paragraphs. There are several other types of suspension bridge, all of which are, however, merely modifications of the common suspension bridge.

The roadway is suspended by slings, usually of S.W.R. from the cables, and consists of transoms, roadbearers, decking and ribbands.

The roadway should be given a camber of 1 in 30, and the cables should be at least 1 ft. above the roadway at the centre. If for any reason it is necessary to reduce the height of the piers, the camber may be omitted, provided due allowance has been made for the stretch of the cables.

Common suspension bridges are the simplest type to construct, but are very liable to distortion under a concentrated load.

2. The *cables* normally consist of wire ropes. For temporary bridges to take foot or pack transport, cordage, sail cloth, thongs of hide, fibres, creepers, grass or boards nailed together may be employed.

It will sometimes be necessary to make up the cables out of wire. The method described in Sec. **54,** should normally be followed, but to save time and labour in a temporary structure, the wires may be bound together without any lay or twist as follows :—

i. Unroll the wires, taking particular care that there are no twists or kinks. This can best be done by attaching one end of a coil to a holdfast and unrolling the coil along the ground away from the holdfast.

ii. Select or construct two holdfasts at a distance from one another equal to the required length of rope, and attach seven of the unrolled wires to one of them.

iii. Attach a length of cordage to one of the wires and stretch it as tight as possible by a suitable number of men hauling on it ; make it fast to the second holdfast, by walking round it twice, keeping the strain on.

iv. Stretch and secure the other wires in a similar manner.

v. Bind the seven wires together into a group with bindings of twine or thin wire at intervals of 1 ft. The wires should not be allowed to override anywhere, and to prevent this a rough gauge of wire twisted into loops should be run along as the binding progresses, thus keeping each wire in its proper relative position.

vi. Bind the requisite number of bundles of seven wires into groups, in a similar way, using bindings of wire at intervals of 3 ft.

The essential requirement is that all the wires should be strained equally. Care must be taken that there is no give in either of the holdfasts. If possible, a spring balance should be used to test the tension of the wire ; otherwise the same number of men should always be used for straining each wire and the men should in each case apply as great a tension as possible.

Even if great care is taken to ensure that the stress is equal in all the wires, the strength of the rope should not be considered as more than 80 per cent. of the total strength of all the wires added together.

If a cable is to consist of two or more ropes, they should be bound together in a similar manner, using tackles, if necessary, to strain them.

3. The *dip* is the term applied to the sag of a cable at the centre of its span. It should be from one-tenth to one-fifteenth of the span. As the dip is increased, the tension in the cables decreases, but the bridge becomes more liable to oscillation.

Due to stretch in the cables and to the taking up of slack, the final dip when the bridge is loaded is considerably greater than that at which the cables were originally adjusted. It is easier to slacken off the cables than to tighten them. The cables should, therefore, be adjusted originally to a smaller dip than the final requirement by an amount equal to from one-fifth to one-tenth of the dip according to the conditions ; the larger the cable, the greater the allowance to be made.

The dip should be measured by nailing small straight edges to the piers level with the required dip and sighting between them.

4. *Stability.*—Suspension bridges are very liable to vertical distortion as concentrated loads cross the bridge, particularly in the neighbourhood of the piers, and to both lateral and vertical oscillations due to the movement of loads on the bridge and to wind pressure. To increase the stability of a common suspension bridge, one or more of the following methods should be employed :—

i. *Waist* the cables at the centre of the gap and splay them over the piers ; the splay should be about one-third of the dip.
ii. Lay the decking at an angle of 45 degrees to the axis of the bridge.
iii. Secure horizontal diagonal timber bracing between the transoms.
iv. Attach guys to at least every second transom and secure them to holdfasts on either side of the gap.
v. Secure inclined struts from the footings of the piers to the point of suspension of the first transom, and wire ties from this point to the second transom.
vi. If the banks are high enough, attach ties to the roadway and anchor them down to the bank.
vii. Use long stiff roadbearers and ribbands, extending over several transoms and breaking joint with each other.
viii. Stiffen the handrails by means of diagonal bracing, which must be securely lashed.

5. *Construction.*—As soon as the line of the bridge has been fixed, the position of the anchorages and piers should be marked out. The early completion of the bridge is dependent on the rapid construction of the anchorages and piers, more particularly of the former ; work on these should be started with the least possible delay.

i. *Field ropeway.*—If the working parties cannot pass easily from bank to bank, some form of light ropeway (Plate **94**) should be constructed across the gap.

A single cable should be erected supported on sheers on either side of the gap. The loads to be taken across the gap are suspended from the cable by a snatchblock, or traveller, and hauled across by ropes and, if necessary, tackles.

The method shown on Plate **94**, has the advantage that the cable can be readily adjusted, either to decrease the stress in the cable or to take up the slack due to stretch in the back guys and attachments.

The cable can be used to erect the sheers. The legs of both sheers should be placed opposite their footings, the crutches lying away from the gap. Sheers B should be temporarily anchored down to the ground, and the crutch of sheers A raised as high as possible by hand, assisted by props and cribwork ; sheers A is finally erected by hauling on the running tackle of the main cable. The back guy of sheers A should then be made fast and sheers B erected in a similar manner.

The sheers should be erected sufficiently far from the edge of the gap to allow for easy attachment and detachment of the loads.

ii. The *piers* are normally made of either round or square timber, tubular scaffolding, if available, is suitable. They consist of a frame with side and back struts and back guys (Plate **93**) ; if the piers are not close to the edge of the gap, the back guys can be replaced by front struts.

The capsill should be secured to the top of the legs by drift-bolts or dogs as for a framed trestle, but the other members may be lashed. It should be protected by hoop-iron, or some similar material, where the cables rest on it. The legs should be directly under the cables.

The back guys should be secured round the capsills, just inside the cable bearings ; the other ends should be attached to the main anchorage.

In order to ensure a direct vertical thrust on the pier, the cables should make equal angles on either side of the pierhead.

The frames should be raised by hand, props being employed at each lift until the back struts can be used. For short spans, fore guys may be used to assist. When erected, the frame should be leaned forward on the back guys to enable the back struts to be put into their footings ; after this has been done, all slack should be taken out of the back guys. For heavy piers, a derrick must be used.

iii. *Raising the cables.*—The cables should be passed across the gap and secured temporarily to the anchorages. Cables of 6-in. S.W.R., or smaller sizes, can be raised by hand, but for larger sizes tackles must be used. These tackles may be suspended from the spars that are intended for use as side struts for the pier. The spars should be erected vertically with the tackles attached to their tips and lashed to the capsills just inside the bearings for the cables. The lower end of the tackles should be hooked into bridles secured to the cables in front and rear of where they are to bear on the capsill.

If the struts are used to raise the cables, side guys must be used on the piers while the cables are being raised. As soon as they are raised, the struts should be secured in their final position, the feet resting on timber footings let into the ground.

If a derrick is used to raise the pier, it should be chosen sufficiently long to enable it to be used for raising the cables as well.

iv. *Making fast to the anchorages.*—Buried anchorages will normally be required ; the method of construction is given in Sec. **61**.

As soon as the cables have been raised on the first pier, the end on the same side of the gap should be made fast to the anchorage by taking a round turn and securing the running end to the standing end by one of the following methods :—

(*a*) Seize the running end of the cable to the standing part nearly up to the extremity of the running end ; open up the wires of this end and bend them back over the seizing ; seize these wires to the standing part.

(*b*) Seize the running end to the standing part with bulldog clips or double-throated clamps (*see* Plate **77**). When these are not available, clips can be improvised from $\frac{1}{2}$-in. or $\frac{3}{16}$-in. diameter round iron and $\frac{1}{4}$-in. W.I. plate.

The cables should then be raised on to the second pier. As soon as this has been done, the slack should be taken out by tackles attached to the cables near the pier head by selvagees, if available ; if not, stopper hitches must be used. As the slack is taken in, the turns on the anchorage should be eased round by hand. The slack should be taken out until the dip is rather less than the final amount required (*see* para. 3, above).

The bearing plates for the cables should be greased.

If the cables do not stretch sufficiently under load to produce the correct dip, the cables should be paid out gradually by first loosening the clip farthest from the anchorage, passing through an inch or two of the running end and then doing up the clip again before undoing the next one. The process may be repeated as necessary.

v. *Placing the transoms.*—The transoms should be placed simultaneously from both ends by means of travellers. A suitable traveller can be made by placing a light spar across the top of the two cables and suspending a plank or spar from it, on which the men securing the transoms can sit. The lashings by which the plank is suspended should be attached to the spar outside the cables. Light tackles should be suspended from either end of the spar to raise or lower the transoms as required. Alternatively, the plank may be slung from shackles running on the cables.

Ropes from both banks should be attached to the traveller to haul it backwards and forwards.

vi. The *slings* normally consist of wire rope. They should be prepared in advance to the correct length after making an allowance for attachments. The required length for each sling can be obtained from Military Engineering, Vol. III, Part I, 1934, Table XXXIII. If the roadway is given a camber, the amount of camber, which will be different for each sling, must be calculated and deducted from the length obtained from the Table.

The slings should be attached to the cables by a round turn and bull-dog clips or seizings ; if the cable consists of two or more ropes, two half-hitches should be included. The fastenings should be prevented from slipping along the cables by collars of spun yarn on either side.

To adjust the slings, the traveller is brought directly over the transom, which is raised or lowered as required by means of the travelling tackles.

vii. The *roadway* should be constructed from both ends simultaneously, each successive bay being built as soon as the transom has been secured. The roadbearers should extend over more than one bay and should break joint as shown on Plate **93** ; they should be securely fixed.

The ribbands should be as long as possible and should be secured to the outer roadbearers by lashings ; these should be protected by wooden cleats nailed to the ribbands so as to avoid their being cut by the traffic.

75. Cantilever bridges

1. *Uses.*—Cantilever bridges (Plate **95**) may be constructed for light loads over spans up to about 60 ft. in length. They have the following advantages :—

i. They are simple to make and require no skilled labour.

ii. They can be made from materials likely to be readily available, *e.g.* forest trees, stones and wire or lashings.

iii. Access to the far bank is not necessary.

But they are wasteful of time, material and labour and are only suitable for light loads.

They can be constructed from any available material but their use will normally be confined to occasions when only round spars cut near the site are obtainable, since in other cases some other type of bridge would be more suitable.

2. *Design.*—Cantilever bridges consist normally of successive layers of timber weighted or tied down at the inshore end. Each layer projects as a cantilever over the layer below it at the outshore end and supports a transom at this end. Cantilevers may be built out from both banks in this way and used to support a span of simple beams over the centre of the gap.

The site must be chosen so that the successive layers can be built below the roadway level, in order to avoid a steep ramp on to the bridge.

The number of cantilevers decreases and the amount of overhang increases as the pier rises. The cantilevered portion of any one layer should not be more than about **5** ft.

3. *Constructional details.*—

i. The cantilevers should be weighted down with stones, rock or earth. Each successive layer should be lashed to the bottom layer with wire, cordage or fibres.

ii. Spars should be placed with their butts outwards and should be adzed to give a good bearing at all points of contact.

iii. The bridge should be built to a camber of up to 1/10.

iv. The bridge should be stiffened by cross-bracing nailed diagonally across the layers and by wire ties from the banks.

76. Frame, sling and tension bridges

1. *Frame bridges* may be used under similar conditions to cantilever bridges. As in the case of the latter, they are only suitable for light loads and will normally only be used where no materials are available other than lashings and spars cut from trees near the site. They are more economical in time, labour and materials than cantilever bridges and should be used in preference to them, provided the gap is suitable for footings for the frames.

i. A *single lock bridge* (Plate **96**, Fig. 1) consists of two lashed trestle frames (*see* Sec. **67**) resting on the sides of a gap and locking into each other. The frames at their junction support a transom on which the roadway is carried. One frame must be made smaller than the other so as to fit into it.

The slope of the frames should not be flatter than 1/2 and the roadway should be given a camber of 1/60. The footings should be exactly opposite each other and at the same level, and should be constructed so that the spars can be easily lowered vertically into them.

A bridge of this type can be constructed by **30** men in about **2** hours for gaps up to **30** ft., provided the materials are available on the site.

ii. A *double lock bridge* suitable for spans up to **40** ft. in length is similar to a single lock, except that the frames lock into a third frame in a horizontal position, thus providing two points of support for the roadway.

2. *Sling bridges* (Plate **96**, Fig. 2) are modified forms of lock bridges and should be constructed in a similar manner. They are suitable for light loads for spans up to **70** ft. in length.

i. A *single sling bridge* consists of two frames locking above the roadway. Slings are suspended from the point of support for the roadway.

ii. *Stiffened treble sling* and *stiffened single sling* bridges (Plate **96**) are further modifications, additional strength being provided by ties passing over piers on the bank to anchorages on shore.

3. *Tension bridges* (Plate **97**) take very much longer to construct than frame and sling bridges, but they can be made to carry light loads over spans up to **100** ft. in length. They should only be used in preference to suspension bridges if suitable cables for the latter are not available.

The transoms may be supported either by two ties, one from a pier on each bank or by a tie and strut on the same bank. The height of the piers should not be less than one-fourth of the span.

CHAPTER XVI

PIERS, ABUTMENTS AND FOUNDATIONS

77. Timber trestle construction and erection

1. *Trestle bridges.*—Trestle bridge piers may consist of :—

- i. *Pile trestles,* in which the legs of the framework consist of piles. They are used only where it is impossible to obtain a satisfactory footing for a framed trestle. Their use and construction are described in Sec. **79.**
- ii. *Lashed trestles* (*see* Sec. **67**), which are suitable for light loads only.
- iii. *Framed trestles,* of round or square timber members framed together. Their construction is dealt with in the following paragraphs.

2. *Framed trestles* are the type most commonly used for medium and heavy bridges to form a supporting pier for the junction of two bridge spans. The piers may consist of one or two bents.

A *bent* is one complete trestle consisting of the following members (*see* Plates **98, 99**) :—

- i. *Legs,* which are vertical, should be arranged so as to come directly under the points at which the capsill is loaded.
- ii. *Rakers,* which are legs set at an angle of from 6/1 to 8/1 to prevent side sway.
- iii. A *groundsill,* which connects the bottoms of the legs and rakers and rests on the foundations.
- iv. A *capsill,* which connects the tops of the legs and rakers, and on which the roadbearers rest.
- v. *Diagonal bracing* on one or both sides.

In *double bent* piers, the two bents must be braced securely together. The load is transmitted from the roadbearers to the bents by (*see* Plates **99, 100**) :—

- i. *Stringers,* which are short lengths of timber placed at right angles across the capsills of the two bents.
- ii. *Bridge seats,* which support the roadbearers and distribute the load to the stringers.

The distance apart of the bents should be not less than one-third the height of the pier, *i.e.* from 5 to 7 ft.

Single bent piers should always be used in preference to double bent piers, provided :—

- i. The piers can be efficiently braced, or strutted, in the direction of the length of the bridge.
- ii. The bearing area on the capsill is sufficient for the ends of the roadbearers. For light or medium loads, corbels (*see* para. 3) may be used to increase the area.

3. *Timber joints.*—

i. *Plain butt joints* (Plate **101,** Fig. 1) should be used for structural work in the field. They should be secured by a drift bolt or dogs. Notched or housed joints weaken the timber and take too long to construct.

ii. *Corbels* or *bolsters* (Plate **102,** Fig. 1) are longitudinal pieces of hard wood or metal used on the top of a leg or capsill to lengthen the bearing. They are suitable only for light and medium bridges. The span should not be considered as reduced by the corbel.

All joints should be treated with a preservative, such as creosote or common tar.

4. *Timber fastenings.*—The types suitable for securing the joints in structural timber are :—

- i. Bolts with nuts and washers.
- ii. Nails, spikes and drift bolts.
- iii. Coach screws.
- iv. Dogs, either square or skew.

Bolts for heavy timber work usually have square heads. The strength of a joint is appreciably increased by using large washers owing to the friction and binding effect of the washer on the timber. For heavy timber work the area of the washer should be 3½ times that of the bolt for soft wood and 2½ times for hard wood. The thickness of washers should be from a quarter to a half the diameter of the bolt. The corners of large washers may be turned inwards to form a grip that will bite the timber when the bolt is tightened up. It is often possible to use a rectangular bearing plate extending the full width of the timber beam in place of a number of washers. Holes should be bored in the timber to take the bolt. The hole should be a driving fit, *i.e.* $\frac{1}{8}$ in. smaller than the bolt for bolts of $\frac{3}{4}$-in. diam. or more, and $\frac{1}{16}$ in. smaller for those under $\frac{3}{4}$ in. Several small bolts staggered make a sounder joint than large ones placed farther apart.

Nails are either cut or wire, and range from 1 in. to 6 in. in length. Wire nails should be used in preference to cut nails. Nailed joints fail in nearly all cases by the drawing out of the nail. A nail should have a length equal to about three times the thickness of the piece of timber held in place by the nail.

Whenever possible, nails should be clenched.

Spikes are from 5 to 10 in. long and from $\frac{3}{8}$ to $\frac{1}{2}$ in. square. The point is wedge-shaped. They should be driven with the pointed edge across the grain, since they are then less liable to split the timber, though the holding power is greater if driven with the pointed edge parallel to the grain.

Drift bolts (Plate **101**, Fig. 7) are pieces of round or square iron, without head or point, driven as a spike, but into a hole previously bored in the timber. They are used extensively in heavy trestle and pile work. A drift bolt acts like a nail, not only preventing lateral movement but also separation of the timbers in a direction parallel to its axis. Heads serve no useful purpose, and merely crush the fibres when driven into the wood. The diameter of the hole for a drift bolt should be $\frac{1}{8}$ in. smaller than the bolt. The hole should be drilled completely through the upper timber and for about three-quarters of the penetration of the bolt into the lower timber. Drift bolts should be $1\frac{2}{3}$ times the width of the timber being held in place, *i.e.* 20 in. for 12-in. by 12-in. timber.

In trestle construction, drift bolts should be $\frac{5}{8}$ in. or $\frac{3}{4}$ in. in diameter. One bolt is sufficient to fasten a leg or raker to the sills at each joint.

Coach screws are large screws with square heads, and are used in heavy work. They are obtainable from $1\frac{1}{2}$ to 12 in. long and from $\frac{1}{4}$ to 1 in. in diameter.

Dogs (Plate **101**, Fig. 7) are generally from 9 in. to 18 in. long, and the teeth from 3 in. to 8 in. long. They are made of iron, $\frac{1}{2}$ in. to 1 in. square section being best. The length of the teeth should be from 10 to 12 times the diameter of iron to get the maximum holding power. For straight dogs the teeth should be shaped as shown on Plate **101** in order to draw the two pieces of timber together and the corners should be square and slightly upset to give strength for driving. The teeth should not be driven within 3 in. of the edge or 4 in. of the end of the timber (*see* para. 7, vi, below, for practical details).

Details of bolts, dogs, nails and spikes are given in Table **43**.

5. *Timber for trestle construction.*—For light and medium bridges time is normally all important and the lightest available timber that is strong enough should be used. Scantlings down to 6 in. by 6 in. or round timber may be used. The lighter the timber, the less the time required for construction and erection.

For heavy loads a more rigid structure is required and, unless time is vital, 10 in. by 10 in. or 12 in. by 12 in. timber should be used.

Round timber is not as satisfactory as square timber; it must be adzed at all points of contact to give a good bearing surface.

To simplify construction, all members of a trestle should consist of the same size of timber.

Composite sills and legs can be made by nailing planks together. The nails should pass through two planks and into a third and should be staggered at intervals approximating to the length of the nails used. The sills should consist of planks on edge, nailed together over the points of support. The legs should consist of planks nailed together face to face, and further secured by planks nailed across the ends as cover plates. Plain butt joints should be used, secured by dogs.

A plank trestle is shown on Plate **103**.

6. *Longitudinal bracing.*—All single bent piers must be braced, or strutted, to prevent collapse in the direction of the length of the bridge. The bracing should consist of 9 in. by 4 in. or any similar timber that is available, secured to the top of one bent and to a point as near the bottom of the next as possible. Cross braces on either side of the bridge should be used, if sufficient timber is available. The last trestle at each end must be securely strutted to the bank.

If cross bracing cannot be fixed owing to the height of the water, or to traffic considerations, the piers must be as efficiently braced as the conditions will allow. Short knee braces between the roadbearers and the legs, and horizontal bracing should be used.

7. *Trestle construction.*—The sequence of construction is :—

i. Choose a level site as near to the final position as possible.
ii. Cut the legs and sills to length. The timber must be cut perfectly true and should be cut in workshops if possible. Battens may be nailed on to the timber to guide the saw.
iii. Square up the frame and windlass it together in two places with lengths of 1-in. steel wire rope.
iv. Mark off the rakers in position, cut them to length and drop them in place. Spike chocks to the sills to keep the rakers in position, outside the raker on the ground sill and inside on the capsill.

v. Make auger holes for the drift bolts; or for the dogs, if used, on one side only. The holes for the legs can be begun while the rakers are being cut.

vi. Drive home the drift bolts. If dogs are used, drive them half home on the first side, turn the trestle over, make holes for the dogs and drive them right home on the far side, turn the trestle back again and drive home the dogs on the first side. Alternatively, after the first dogs have been driven half home, the trestle may be erected in a vertical position and all dogs driven in the correct sequence without any further turning of the trestle. For light trestles which can be easily turned over, dogs should be used in preference to drift bolts, since the time spent on construction will be less.

vii. Fix the bracing on the first side. If dogs are used, the bracing cannot be fixed until the dogs have been driven right home. The trestle should be carefully squared up before the bracing is put on.

viii. Turn the trestle over, or upright, and fix the bracing on the other side. The bracing should consist of planks of 9 in. × 3 in. or 9 in. × 4 in. or similar timber extending on each side from the outside of the capsill to the outside of the groundsill. It must be firmly secured with nails or spikes at all points of contact (*see* Plates **98** and **99**). If there is no centre leg, the two braces should be bolted together where they cross with a chock between them. If the bracing does not lie flat against all the members owing to unequal sizes of timber, packing blocks should be used to secure firm contact.

8. *Trestle erection.*—Trestles can be lifted and carried by hand, but if made of timber heavier than 9 in. × 9 in., this is very hard work. Heavy trestles should first be erected into a vertical position; they can then be easily moved on wooden rollers in the direction of their length.

Trestles of timber larger than 6 in. × 6 in. cannot normally be erected by hand. The capsill should be lifted as high as possible by hand on to packing. The trestle can then be raised into a vertical position by means of cordage tackles. Foot-ropes, head-ropes and anchorages will be necessary; they should be prepared during trestle construction. If the initial pull cannot be exerted from an angle, *i.e.* from the top of a bank, a light lever should be used.

In wet gaps the trestles must either be launched down ways of rails or timber or carried into position on boats or pontoons. The groundsill should be weighted.

In the case of trestles to be erected on the top of a semi-demolished pier, the hauling and preventer tackles that will later be used for launching the girders may be employed. The two tackles should be attached to a single point, from which the trestle is suspended. A double bent pier may be erected complete in this way.

78. Crib piers

1. Cribwork consists of timber, sleepers, rails, etc., built up in layers, square or rectangular in plan. The timbers, etc., in each layer are spaced out parallel to each other, and are at right angles to those in the layer below. Cribwork may be used for piers or in abutments.

Up to a height of about 8 ft., crib piers can be erected more quickly than trestle piers. They may be useful on soft ground, as they provide a larger bearing area than the ground sill of a trestle. Timber crib piers may be placed in shallow water by being floated into position and sunk by filling a prepared tray at the bottom with stones.

Crib piers require a large amount of material, and are not economical for heights of over 8 ft. An accurate section of the ground must be taken and the bottom of the cribwork shaped to conform to it, as it is difficult to adjust any tilt.

Steel cube piers are suitable for medium and heavy bridges.

2. The *principles of construction* of crib piers (*see* Plate **104**) are :—

i. The width of the base should never be less than one-third of the height.

ii. The ends of the pier should be given a batter for stability. This will not be possible if only short lengths of timber, etc., are available, as in the case of a sleeper crib pier.

iii. The points of support, *i.e.* where successive layers cross, should come immediately under the load and should be carried in a direct line from the top to the bottom of the crib.

iv. Each successive layer must be securely fastened to the layer below. Bolts, nails, spiles, wire, cordage, etc., may be used. For work of a very temporary nature, these fastenings may sometimes be omitted.

v. Each successive layer must be level. If the foundations are not level, they should be built up to a level surface, on which the remainder of the crib pier is constructed.

vi. With round timber, the points of contact must be adzed so as to give a good bearing.

3. *Steel cube piers* are suitable for medium and heavy bridges. They are particularly useful in conjunction with R.S.Js. to provide crossings over wide and dry gaps, or gaps with shallow water and no current. They are difficult to place in running water.

Each cube weighs 3 cwt. 1 qr., and will support a weight of 40 tons, provided the weight is brought only on to the corners.

The height can be varied in multiples of **3** ft., and can be made up to any intermediate level by the addition of timber crib work.

Single cube piers are used up to 9 ft. in height, double from 9 ft. to 18 ft., and treble from 18 ft. to 24 ft.

The use of the piers, however, for a height greater than 18 ft. is seldom advantageous.

Piers must be built on a horizontal base and it is important that the piers should be kept horizontal as they rise. Wherever practicable, it will be best to provide a level concrete footing. Longitudinal bracing should be used at every **3** ft. of height.

4. *Tubular scaffolding* is described in Military Engineering, Vol. III, Part II, Pamphlet No. 4.

79. Piles and pile driving

1. *Piles* are columns of timber, iron, steel or concrete driven into the ground.

2. A *bearing pile* is one that is driven into the ground vertically in order to support a load. This is the only type in common use in the field.

Bearing piles may be supported in two ways :—

i. By being driven until the bottom of the pile reaches firm ground, on which it is supported.

ii. By friction between the sides of the pile and the ground.

In case (i) the pile receives little or no lateral support, and the load that it can carry is limited by its strength as a column.

In case (ii) the load is limited either by the friction between the ground and the surface of the pile, or by the strength of the upper part of the pile as a column.

As a rule, piles are supported by a combination of (i) and (ii).

3. *Timber piles* are generally used in the field, either of round or square section. Spars should normally be driven tip downwards ; but where the bearing power of the pile is dependent on the bottom of the pile resting on firm ground, they should be driven butt downwards. Greater care must then be taken in driving, as the top is smaller to receive the blow.

When it is necessary to lengthen a timber pile, a plain butt joint with timber or iron fish plates should be used.

4. *Shoes.*—In soft or average ground, timber piles should be sawn off square to the length of the pile ; no shoe is necessary and the end of the pile should not be pointed, but should be given a slight chamfer to protect the corners.

But in hard ground or in loose ground containing large boulders which it is necessary to split, the pile should be shod with a metal shoe. This shoe is intended to protect the end of the pile and so to increase the penetration, and should, therefore, be blunt. It should consist of a chilled casting with wrought iron straps fixed by bolts or spikes (*see* Plate **105**). The end of the pile should be carefully squared, and the shoe should be made to fit closely, so that the point of the timber transfers the blow to the shoe and the strain does not come on the fastenings. The point of the shoe must be central with the axis of the pile in order that driving may be true.

If a chilled casting cannot be made, the end of the pile should be brought to a chisel edge and shod with 4 in. × $\frac{1}{4}$ in. or 4 in. × $\frac{3}{8}$ in. iron straps.

5. *Rings* (*see* Plate **105**, Figs. 1 and 2) are nearly always necessary, especially in very hard ground, to prevent the head of the pile from splitting under repeated blows of the monkey. They should be made of mild steel of from $1\frac{1}{2}$ in. × $\frac{3}{8}$ in. to 4 in. × 1 in. in section, according to the size of the pile. The lower inside edge should be slightly chamfered.

They can be driven on with a blow of the monkey after the pile is in position.

The head of the pile must be sawn off square whether a ring is used or not.

6. *Piled piers* should only be used if it is impossible to obtain a satisfactory footing for framed trestles. They should be designed similarly to framed trestles, but the piles should not be spaced closer than three times the diameter of a pile, centre to centre.

The piles should be arranged directly under the points at which the capsill is loaded. All piles should be vertical. No attempt should be made to drive " batter " piles to correspond to the rakers of a framed trestle.

Diagonal bracing should be fixed as low as possible, but not below water level, as follows :—

Bents less than 8 ft. high, if the feet are securely held by the ground ...	no bracing.
Bents from 8 to 12 ft. high	a single cross.
Bents from 12 to 16 ft. high	a double cross.

Longitudinal bracing should be provided for all single bent piers above 12 ft. in height. The two bents of a double bent pier should be braced together.

The *capsill* is secured to the legs by dogs or bolts in a similar manner to the capsill of a framed trestle. It is essential that the heads of the piles should be cut off at the same level. The correct cut off should be marked on the two outside piles of the pier, and battens with straight upper edges, long enough to extend entirely across the pier, levelled up and nailed on each side of the piles. The piles can then be cut off at this level.

The men sawing off the tops of the piles must be provided with a platform on which to stand, either on floating supports or secured to the piles themselves.

Piles should not be cut off below water level, as this operation is most difficult and entails much labour.

7. *Pile-drivers.*—

i. The simplest form of pile-driver is a maul. Light timber spars can be driven into soft ground with a maul to form supports for footbridges.

ii. *Pile-driving frame and monkey.*—For bridges to take loads greater than that of foot traffic, frames similar to those shown on Plates **106** and **107** should be used. The frame consists of a timber framework supporting two vertical pieces of timber, called *leads*, to which both the pile and the weight, called a *monkey*, are secured. At the top of the leads is a pulley, over which the rope for raising the monkey passes.

The pile should be held in position by a bolt, which passes through the head of the pile, and through a block which slides between the leads and keeps the pile central; the bolt is secured to a plate at the back overlapping the leads.

The monkey should be secured to the leads in a similar manner to the pile, except that instead of a block, the monkey itself may be shaped to fit in between the leads.

The plate at the back of the monkey should be fixed with loose bolts, so that they can be easily repaired if damaged; instead of the bolt and nut, the bolt may have the end slotted to take a wedge.

The monkey is raised by a rope, worked by hand or by a steam or petrol driven winch; the rope is attached to the monkey by a *trip-hook*, which fits into an eye at the top of the monkey. When the monkey reaches the required height, the trip-hook is released by a *trip-rope* and the monkey allowed to fall free on to the head of the pile. The trip-hook and eye should be designed so as to allow the monkey to be hoisted to the full height of the frame.

The weight of the monkey should preferably be from 1½ to 2 times the weight of the pile, but for work in the field the weight must be such that it can be readily manhandled and should not exceed 10 cwt.

The frame must be set true and plumb and must be firmly fixed. The centre of the head of the pile should be under the centre of gravity of the monkey.

iii. A *portable pile-driver* convenient for use in the field is shown on Plates **106** and **107**. The framework is designed so that it can be rapidly constructed on the site out of local materials; the monkey, pulley and trip-hook can be obtained from stock at the base.

The weight of the frame should be kept below 10 cwt. for easy handling. No iron guides need be provided for the monkey. Two platforms are provided to enable the men to stand close to the monkey and attach the hook. To give greater stability the base of the frame should be square and not triangular. One guide rope should be provided at the back of the frame, but side guys are seldom necessary.

This pile-driver can be used for driving piles up to 12 in. × 12 in. in size, in normal ground.

iv. *Improvised pile-drivers.*—Pile-drivers suitable for light work can be readily improvised.

Plate **108** shows the use of two service trestle legs. The monkey consists of a block of wood about 200 lb. in weight, through which two holes are bored to take iron bolts. These bolts work up and down between the trestle legs, which act as guides and keep the monkey in position. The monkey should be bound top and bottom with wire.

v. Plate **109** shows a method of driving known as the ringing method, which is similar to that employed for a Norton Tube well.

Plate **110** shows the use of two steel rails.

8. *Pile-driving.*—

i. The *set* of a pile is the term applied to the penetration of the pile under each blow of the monkey. It is normally measured in inches.

With a monkey weighing from 15 cwt. to 1½ tons, piles should be driven until the average set for the last four or five blows is from ½ in. to 1 in. With an 8¾-cwt. monkey, the set should be from ¼ in. to ¾ in.

The set may be measured by marking on the leads the position of the head of the pile after each blow of the monkey.

ii. *Brooming.*—As a result of the constant blows of the monkey, the fibres at the head of the pile become crushed; this is called brooming. It only affects the head of the pile, as the pile ring prevents splitting, and, if the broomed head is cut off, the timber will be found to be quite sound.

The brooming of the head of the pile reduces the effect of the blow of the monkey.

iii. *Springing* will occur :—

(*a*) If the pile is crooked.
(*b*) If the head of the pile is not square, causing the monkey to strike on one side only.
(*c*) If the pile and direction of fall of the weight are out of line.

Excessive spring results in a loss of energy and should be avoided.

iv. *Bounce.*—A very slight bounce of the monkey occurs at every blow under good conditions, but decided bouncing may occur :—

(*a*) When penetration ceases.
(*b*) If the hammer is too light.
(*c*) If the fall is too great.
(*d*) If the head of the pile is crushed.

v. *Overdriving* is a frequent cause of injury to piles. It occurs through too violent or too continuous hammering. The fall of a monkey weighing 15 cwt. to 1½ tons should not exceed 10 ft.

Overdriving is indicated by excessive springing of the pile or bouncing of the hammer, or the pile may suddenly change direction, in which case it is probably broken.

Injury due to overdriving usually takes the form of brooming or splitting of the pile.

vi. A *dolly*, or follower, should be used when it is necessary to drive a pile below the leads. The simplest form is a length of pile ringed at both ends and resting on the pile head; it is kept in place by a dowel at the bottom and by a gauge bolt at the top.

The dolly reduces the efficiency of the blows, in some cases where there is much vibration, by as much as 50 per cent.

vii. *Methods of supporting the pile-driver.*—In all pile-driving operations and particularly for rapid work in the field, the correct positioning of the pile-driver and of the pile is a

more difficult operation than the actual driving of the pile. The pile-driver may be supported in one of three ways :—

(*a*) *On a temporary staging.* This is the most satisfactory method. The service trestle or pontoon equipment makes a very suitable staging; the trestles are particularly suitable, since the height of the staging can be adjusted as required. The simplest method is to build a complete bridge of servce equipment on the same alignment as the pile bridge.

(*b*) *On a raft.* Provided there is ample waterway to float the raft, this method has the advantage that the pile-driver can be easily moved to any required position. In either a wind or a current, however, it is extremely difficult to maintain the raft in exactly the correct position.

If a light raft is used, the counterweight must be adjustable; otherwise it will be difficult to drop the pile vertically in position, since the raft will tilt under the weight of the pile.

In order to ensure that the raft is in the correct position and to maintain it there, a timber distance frame should be made and floated into position between the bent that is already driven and the one about to be driven.

(*c*) *On cantilevers.*—Light pile-drivers can be supported at the end of cantilevers of timber, rails or R.S.Js., if the distance between bents is not more than 10 to 12 ft. But this method takes a long time and should only be used if no other method is possible.

viii. *Practical details :—*

(*a*) In order to keep the pile on the move drive as fast as possible and without stopping.
(*b*) A heavy hammer with a low fall should generally be used. A continuous series of light blows is more effective than heavier blows at longer intervals.
(*c*) The rope for raising the monkey can first be used to raise the pile into position; the pile is then temporarily lashed to one side while the monkey is attached and raised.
(*d*) If the winding gear is not fixed to the piling frame, the frame must be firmly secured with foot-ropes or pickets to prevent it from being pulled out of position.
(*e*) If the base of the monkey is larger than the head of the pile, distance pieces should be fixed to the leads to ensure that the pile remains with its centre under the centre of gravity of the monkey.

(*f*) The first few blows should be light until the pile is firmly fixed. The blows should then be increased until the maximum drop is reached.

(*g*) If the pile suddenly checks, to discover the reason, reduce the blows to, say, 4 ft., and drive quickly for a short time. If this does not start the pile again, leave it and proceed to the next pile. If this checks at the same level, it may be assumed that a good bearing stratum has been reached; if not, the first pile has probably met with a local obstruction, such as a boulder or tree, and driving should continue with care not to overdrive, until the obstruction is either broken or displaced.

80. Abutments, approaches and foundations

1. *Masonry abutments.*—Existing abutments of brick or stone should be made use of whenever possible. If partially demolished, they should be roughly levelled at a height below which there are no large cracks. No attempt should be made to form a smooth surface on which to place the timber.

In the field, timber abutments must normally be used, since there will not be sufficient time for the construction of brick or masonry abutments.

2. A *timber bridge abutment* consists of three distinct parts :—

i. The bank seat which supports the end of the bridge-span.
ii. The connection between the bridge and the approach road.
iii. The retaining wall or other arrangement to prevent the earth breaking away beneath the bank seat.

3. The *bank seat* normally consists of two parts, designed to distribute the load to the ground :—

i. A bridge seat, upon which the end of the bridge rests.
ii. The mudsills upon which the bridge seat rests.

The following principles should be followed when constructing bank seats :—

i. The mudsills should be set about 2 in. higher than their final position to allow for settlement, and should be carefully levelled in both directions.
ii. The bridge seat should be placed centrally on the mudsills. Unsymmetrical loading will lead to uneven settlement and eventual collapse.
iii. If the bank is dug too deep, the correct level should be regained by packing up with timber or some hard material, and not by refilling with earth.
iv. The natural slope of the earth should not be exceeded. Sand, gravel, dry clay, loam and mixtures of these will stand at a slope of 3/4, wet clay or loam at 1/2.
v. The area of the mudsills should be such that the bearing pressure of the ground is not exceeded. If the area of the bridge seat is sufficient, no mudsills need be used.

4. An *end dam* of planks should be placed across the ends of the roadbearers and fixed to them, to prevent the roadway from caving in between the roadbearers. It should extend slightly beyond the natural slope of the earth at the sides of the roadway.

5. *Retaining walls* of sheeting or planking held in place by pickets or piles or of cribwork must be constructed to prevent the earth breaking away from beneath the bank seat, unless the bank seat is set well back from the edge of the gap.

6. The *approaches* at both ends of a bridge are of paramount importance. If no suitable road metal is available, a timber roadway should be constructed. If the approach is very firm it may not be necessary to use approach planking, but if the roadway has been excavated behind the end dam, or if it needs filling up, a back filling of broken brick or masonry placed and tamped in layers about 6 in. thick must be used.

The road surface at the end of the bridge or approach planking should be of broken stone properly compacted, and will require careful and frequent maintenance. If made of earth or even gravel the surface cuts up very quickly and becomes almost impassable in wet weather.

The approaches must be so made that vehicles pass on to the bridge as smoothly as possible. If approach planking is used, it should be originally an inch or two higher than the bridge surface, so as to allow for settlement. When ramped approaches are necessary, the slope for animals and wheeled vehicles should not be steeper than 1/10; in ramping down on to a bridge, the approaches should be level for 3 or 4 yards immediately before the bridge.

Except in close proximity to the enemy the approaches must be clearly outlined by stout pickets painted white; where this is impossible tracing tapes must be used.

7. *Foundations* may consist of :—

i. Brick or masonry.
ii. Piles.
iii. Timber mudsills.

Brick or masonry forms the best foundation, but can rarely be employed in the field, and timber mudsills are generally used.

They consist of timbers laid symmetrically under the trestle at right angles to the ground sills to increase the area of bearing on the ground.

They should be laid in accordance with the principles given in para. 3, above.

Piles must be used where the ground is too soft to support timber footings, or where the foundations are liable to scour.

CHAPTER XVII

BRIDGE DESIGN AND CALCULATIONS

81. Impact

1. The loads that a bridge has to carry may be divided into :—

i. The *live load*—the weight of the traffic of all kinds that crosses the bridge.

ii. The *dead load*—the weight of the bridge itself and of any other material resting on the bridge, though not essential to its stability, such as sand spread to deaden the noise of animals' feet, or snow.

2. *Impact factor*.—The distinction between dead and live loads is most important, as, weight for weight, live loads bring a greater stress on the members of the bridge, owing to shocks and vibrations set up by their sudden impact.

In calculations, an allowance for impact should be added to the live loads to convert them into what is called their *equivalent dead loads*.

This allowance should be 50 per cent. (*i.e.* the live load should be multiplied by $\frac{3}{2}$) for all members of a road bridge, except that :—

i. An allowance of only 25 per cent. should be made for any member of a bridge, of which the unsupported span exceeds 38 ft.

ii. An allowance of only 25 per cent. should be made for all members of a bridge supported on floating piers.

iii. No allowance need be made for :—

(*a*) Infantry or cavalry when the figures for *crowded at a check* or a *disorganized mass* are used, since the men or horses are then so close to each other that they cannot be causing any impact.

(*b*) Track vehicles, if the tracks are sprung.

3. The amount of impact caused by a road vehicle is entirely dependent on the state of the surface of the roadway.

It is, therefore, especially necessary to maintain the roadway of the bridge and the connection between the bridge and its immediate approaches in good condition, so that the trafic does not bump on to the bridge, and to design as straight and level an approach as possible. Anti-slipping slats, where fitted to the roadway, should not be larger than 4 ft. 6 in. × 2 in. × ¾ in. high.

4. *Track vehicles.*—The existing whole track vehicles distribute the weight evenly over several feet run of the bridge, and, moreover, the springing of the tracks is such that the weight will be distributed, even though the decking is not quite level. For such vehicles, therefore, no allowance for impact is necessary.

When a tank approaches a bridge, it has no tendency to push the shore transom forward, which is a marked tendency with wheeled vehicles. Instead, the tracks anchor the shore transom to the ground, so long as any other portion of the track still rests on the ground.

Sudden acceleration sets up large horizontal stresses in the roadway. This may be sufficient to cause the shore transom to move off the bank seat and the bridge to collapse. The shore transom should be securely anchored with pickets or in some other way.

Swinging produces large torsional stresses, and some form of bracing is necessary between the roadbearers to keep them upright.

Drivers should cross military bridges at an even speed and should be warned before crossing of the danger of sudden acceleration and of swinging.

82. Military loads

1. *Infantry.*—Infantry in marching order average 200 lb. a man (live load).

Infantry unarmed average 160 lb. a man (live load).

The weight of infantry in marching order, assuming they are crowded at a check to the greatest extent possible, short of losing their formation, can be taken as :—

Equivalent dead load a ft. run of bridge.

Single file	140 lb. or 1¼ cwt.
File	280 lb. or 2½ cwt.
Fours	560 lb. or 5 cwt.

When infantry lose their formation and crowd together in a disorganized mass they may bring the following weight on the bridge surface :—

Equivalent dead load a sq. ft.

In marching order	133 lb.
Unarmed	175 lb.

2. *Cavalry.*—The weight of cavalry in marching order, assuming they are crowded at a check to the greatest extent possible, short of losing their formation, can be taken as :—

Equivalent dead load a ft. run of bridge.

Single file	200 lb. or 1¾ cwt.
Half sections	400 lb. or 3½ cwt.

A cavalryman and his horse in marching order average about 1,400 lb. About three-fifths of this is borne on the forelegs. It must, therefore, be assumed that a weight of about 840 lb. live load can be brought on to one foot of a cavalryman's horse.

Cavalry in a disorganized mass weigh about 120 lb. a sq. ft. of bridge (equivalent dead load).

3. *Animals.*—The weights of animals are given in Military Engineering, Vol. III, Part I.

4. *Vehicles.*—All military vehicles are classified according to the type of bridge required to carry them (*see* Chapter X). Table 53 shows the classification to which each vehicle belongs and gives the effect of these loads for each classification over varying spans for purposes of calculation.

Details of the dimensions and weights of each vehicle (light loads only) are given in Table 53. Other loads are given in Military Engineering, Vol. III, Part I.

5. *Dead loads.*—In calculating the dead load on a bridge member the weight of the member itself must be included in addition to any other member or material that it may be supporting. It should be noted, however, that Tables 51 and 52 make allowance for the weight of the members themselves.

The weights must be calculated according to the actual sizes of the materials used. These will not always be known in the early stages of the calculations, and an estimate must be made based on previous experience.

As a rough guide, superstructure weighs 1 cwt. a ft. run for a 5-ft. roadway and 2 cwt. per ft. run for a 10-ft. roadway for medium loads.

When calculating the dead load, the weights of the various materials may be taken as :—

Timber	40 lb. a cu. ft.
Sand or earth	100 lb. a cu. ft.
Snow	10 lb. a cu. ft.
Brickwork or masonry ...	150 lb. a cu. ft.
Concrete	100 lb. a cu. ft.
Iron or steel	450 lb. a cu. ft.

When the sizes of all the members have been finally decided, it will sometimes be necessary to check the original calculations, which were based on estimate of the sizes that would be required.

83. Factor of safety

1. All calculations are based on the breaking strengths of the materials used; the values for these breaking strengths are assessed as the result of experiments. It is obviously unsafe to stress any material in a structure up to or even close to the breaking limit.

In order to allow for slight variations and defects in the material, and to allow for stresses that may be set up, though not considered in the calculations, and in order to ensure that the material is not strained beyond its elastic limit, the breaking strength is divided by a factor, called the *factor of safety*.

The value of this factor will vary according to the material and the structure in which the material is used from 2 to 30 or even more. For general field use, a factor of safety of 4 should be allowed. This may be reduced to 3 occasionally in temporary structures.

84. Roadbearers

1. *Determination of the load*.—A load concentrated at the centre of a span sets up greater stresses in the roadbearers than would be the case if the same load were distributed along the whole length of the span. It has also been shown that a live load sets up greater stresses, weight for weight, than a dead load.

Any concentrated live load or series of concentrated live loads may be reduced to what is called an *equivalent uniformly distributed dead load* (E.U.D.D.L.), that is, the dead load, which if evenly distributed over the whole length of the span, would set up the same stresses.

Table 54 gives varying spans for the maximum E.U.D.D.Ls. that can occur for each of the different classes of military loads. The E.U.D.D.Ls. due to infantry and cavalry are given in Sec. **82.**

As a vehicle crosses a bridge, it may wander from side to side of the roadway, and the proportion of its weight that any one roadbearer carries will depend on the position of the vehicle. It cannot, therefore, be assumed that the load is carried equally by all the roadbearers. With a roadway of approximately 10 ft. the following assumptions should be made :—

Number of roadbearers	*Maximum proportion of the total load that any one roadbearer may have to take*
4	$\frac{2}{5}$
6	$\frac{1}{4}$
8	$\frac{1}{5}$
10	$\frac{1}{6}$
12	$\frac{1}{8}$

The roadbearers must be arranged symmetrically and grouped as nearly as possible underneath that part of the roadway on which the wheels of vehicles will come.

The total dead load on the roadbearers may be calculated from the figures given in Sec. **82, 5**. The dead load will be distributed evenly over the roadbearers, and each one will therefore take an equal proportion of the total.

By adding together the equivalent dead load (due to the live load) and the actual dead load (due to the superstructure, etc.), the total load that any one roadbearer may have to take is obtained in the form of the E.U.D.D.L.

When considering a single concentrated live load, the equivalent *distributed* live load is double the concentrated live load; the necessary impact allowance must then be added to bring it to the equivalent distributed *dead* load.

Thus, a concentrated live load of 1 ton is equal to a distributed dead load of $1 \times 2 \times \frac{3}{2} = 3$ tons.

2. *Strength of roadbearers*.—The safe E.U.D.D.Ls. that can be carried by square timber, round timber, rails and R.S.Js. for carrying spans are given in Appendix IV. These tables allow for the weight of the roadbearers themselves.

Thus to determine the size of roadbearers required :—

i. Determine the total distributed dead load equivalent to the live load under consideration either :—
   (*a*) In the case of classified military load, by means of Table 54.
   (*b*) In the case of infantry and cavalry, by means of the figures in Sec. **82.**
   (*c*) In the case of a single concentrated load as shown at the end of para. 1, above.

ii. Using Tables 51 and 52 as guides, assume the number of roadbearers that are likely to be required.

iii. Using the figures in para. 1, above, determine the live load that one roadbearer may have to take.

iv. Using the figures in Sec. **82**, 5, determine the dead load that one roadbearer may have to take.

v. Add iii. and iv. together.

vi. From Tables 51 and 52 choose the size of roadbearers required.

85. Calculations for beams

1. *Timber.*—The following rough formulae may be used to find the safe working loads for timber beams :—

Where, W is the safe equivalent uniformly *distributed dead* load in cwt.,
b is the breadth of the beam in inches,
d is the depth of the beam, or diameter of round spar, in inches,
L is the span in feet.

i. *Beam supported at both ends.*—

Rectangular $$W = \frac{bd^2}{L}$$

Circular $$W = \frac{6}{10} \times \frac{d^3}{L}$$

ii. *Cantilevers.*—

Rectangular $$W = \frac{1}{4} \times \frac{bd^2}{L}$$

Circular $$W = \frac{1}{4} \times \frac{6}{10} \times \frac{d^3}{L}$$

These formulae allow for the use of unselected timber and for superstructure weighing up to $\frac{1}{6}$W, with a factor of safety of about 4.

The safe concentrated dead load is one-half the safe equivalent uniformly distributed dead load as obtained from the above formulæ.

Rectangular timber beams should be used on edge, but when used on edge, if calculated by the above formulæ, the depth of the beam should not be more than :—

One-tenth of the span under a uniformly distributed load ;
or
one-fitfh of the span under a concentrated load.

2. R.S.Js. (I girders). The following rough formulae may be used to find the safe working loads for rolled steel joists :—

Where, b is the breadth of the girder in inches,
d is the depth of the girder in inches,

t is the average thickness of one flange of the girder in inches,
L is the span in feet,
W is the safe equivalent uniformly *distributed dead* load in *cwt.*

i. *Beams supported at both ends.*—

$$W = \frac{100bdt}{L}$$

ii. *Cantilevers.*—

$$W = \frac{25bdt}{L}$$

In order that the girder may not be too whippy, the depth should not be less than one-twenty-fourth of the span.

3. *Examples.*

i. What is the safe concentrated load on a 9 in. × 6 in. timber beam over a span of 9 ft. ?

W (the safe equivalent uniformly distributed dead load in cwt.).

$$= \frac{bd^2}{L} = \frac{6 \times 9 \times 9}{9} = 54 \text{ cwt.}$$

The safe concentrated load is half of this, *i.e.* 27 cwt.
The safe *live* concentrated load = 27 × $\frac{2}{3}$ = 18 cwt.

ii. What size of spar is necessary to take a dead load of 2 tons distributed over a span of 12 ft. ?

$$W = \frac{6}{10} \times \frac{d^3}{L} \quad \therefore d^3 = \frac{2 \times 20 \times 10 \times 12}{6} = 800$$

If d = 9 in., d^3 = 729. If d = 10 in., d^3 = 1,000.
Therefore, a 10-in. mean diameter spar is required.

ii. What distributed live load will a 9 in. × 4 in. R.S.J., with an average thickness of one flange of $\frac{1}{2}$ in. take over a 10-ft. gap ?

W (the safe equivalent uniformly distributed dead load in cwt.).

$$= 100\frac{bdt}{L} = \frac{100 \times 9 \times 4 \times \frac{1}{2}}{10} = 180 \text{ cwt.}$$

The safe distributed *live* load is $\frac{2}{3}$ of the dead load =
180 × $\frac{2}{3}$ = 120 cwt. = 6 tons.

86. Piers and abutments

1. *Determination of the load.*—To calculate the strength of trestles, the area of bank seats, etc., it is necessary to deter-

mine the load borne by the supports ; the load on a support is known as the *end reaction* at that support.

i. *Single span.*

(*a*) *Load distributed evenly over the whole span.*—The maximum end reaction is one half of the total load.

(*b*) *A single concentrated load crossing the span.*—The maximum end reaction is equal to the load.

(*c*) *Several concentrated loads crossing the span.*—In this case accurate calculations are complicated.

For all classified loads, the maximum end reactions should be read direct from Tables in Manual of Military Engineering, Vol. III, Part I.

As a rough estimate only, the maximum end reaction may be taken as either one-half of the total loads on the span or as equal to the greatest load, whichever is greater.

ii. *Several consecutive spans.*—When calculating the maximum end reaction on a pier at the junction of two spans, it should be assumed that both spans can be fully loaded simultaneously and that the pier has to take the sum of the two end reactions. This is not always true, but the error is on the side of safety.

In all cases, the live load must be converted to its E.U.D.D.L., and the dead load of the superstructure must be added. Each support has to take one-half of the weight of superstructure.

2. *Bearing area.*—The material, of whatever nature, on which the ends of the span rests, must be strong enough to withstand crushing. The total bearing area between the supports and the ends of the roadbearers, and between the supports and the ground, must each be checked.

It may be assumed that the total load is distributed evenly over the whole area of support.

The maximum safe allowable loads on various materials, from the point of view of crushing, are :—

Material	*Safe load in tons a sq. ft.*
Marshy ground	⅜
Average ground, consisting of a mixture of loam and gravel	1½ to 2½
Solid clay	4
Compact gravel or chalk	6
Second class brick in P.C. mortar ...	12
Ordinary good sandstone	13
First class brick in P.C. mortar	20
Ordinary good limestone	25
Portland cement concrete	30
Granite	50
	Safe load in lb. a sq. in.
Timber	300

3. *Piers.*—The total load on a pier should be determined as described in para. 1, above.

The bearing area of the bridge seat or capsill must be such that the load does not exceed 300 lb. a sq. in.

The legs of the trestle (whether piled or framed) must be arranged so that they directly support the capsill at the points on which it is loaded (*see* Plate **98**).

The legs must be strong enough to take the load, which may be assumed to be equally distributed between them. Each raker should be considered as equal to ⅔ of a leg. Thus a double-bent trestle, each bent of which consists of 3 legs and 2 rakers, is equivalent to 8⅔ legs.

The total load on the pier should be divided by the equivalent number of legs ; this gives the load on one leg. The size of timber required can then be selected from Table 48.

The bearing area of the ground must be checked, mudsills (*see* Sec. **80**) being used if necessary to distribute the load.

In the case of crib piers, only direct crushing need be considered.

CHAPTER XVIII

IMPROVISED FLOATING BRIDGES AND RAFTS

87. General

The service equipment is discussed in Chapter X. The details of the equipment and drill for erection are issued as separate pamphlets that form Military Engineering, Vol. III, Part II.

Occasions will arise when improvisation from local resources is necessary either to supplement the equipment or in special cases when it is not available.

In this chapter the principles involved in building floating bridges and rafts are discussed, and some examples are given of types that can be made from improvised materials.

88. Buoyancy

The actual buoyancy of a closed vessel, such as a barrel or petrol tin, is the weight of water it will displace when fully immersed less its own weight. To find the actual buoyancy, therefore, the volume and weight of the vessel must be determined. One cu. ft. of water weighs 62·5 lb., thence, if the volume of the vessel is V cu. ft. and its weight is W lb., the actual buoyancy will be $62{\cdot}5V - W$ lb.

The safe buoyancy for bridging purposes, so that the roadway will be clear of the water, is taken as nine-tenths the actual buoyancy, if the vessel is water tight, such as a barrel with the bung closed. In the case of open boats two-thirds the actal buoyancy is usually taken as safe.

Table 11, p. 197, gives the buoyancy of various barrels in commercial use.

Where the capacity of the barrel is not known the *actual buoyancy* in lb. can be found from the following formula :—

$$5C^2L - w.$$

Symbols as in Table 11, p. 197.

The buoyancy of certain boats used in the Royal Navy is given in Military Engineering, Vol. III, Part I, 1934, Table XXXIV.

TABLE 11.—BUOYANCY OF VARIOUS BARRELS.

Name of barrel	Capacity in imperial gals.	Dimensions			Weight when empty = *w*	Actual buoyancy
		Extreme bung diameter	Extreme length exclusive of projections measured along the stave = L	Circumference at ¼ length = C		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		in.	ft.	ft.	lb.	lb.
Ledger	170	38·5	4·52	9·33	252	1,736
Butt	108	33·3	3·97	8·09	174	1,125
Puncheon	72	30·7	3·20	7·57	140	777
Hogshead	54	28·6	2·76	7·05	119	567
Barrel	36	25·3	2·42	6·23	88	382
Half hogshead	26	22·7	2·12	5·61	65	269
Kilderkin	18	20·3	1·81	5·02	49	185
Small cask	14	18·3	1·76	4·49	32	146
,, ,, ...	6	13·8	1·37	3·40	20	60

The available buoyancy of a boat may be determined by loading it with unarmed men to 12 in. of the gunwales and multiplying the number of men by 160. This gives the available buoyancy in lb. In rough water or in a violent current a margin of safety must be allowed.

89. Rafts

(For buoyancy, *see* Sec. **88**.)

1. When there is insufficient material for the construction of a bridge, or when it is only necessary to establish a ferry, rafts may be used, constructed of bridging equipment, of barrels, steel drums, boats, logs, empty tins, planks or, as a temporary measure, of waterproof material, such as tarpaulins or ground sheets, stuffed with straw, heather, ferns, etc. As an emergency measure it is possible to get small vehicles such as a light car across a river by wrapping them up in a waterproof cover (*see* para. 11, below). Cork floats are useful when the ferry may be subjected to heavy shell fire, but such floats are heavy to handle. Rafts may be towed, rowed, poled, propelled by an out-board motor, hauled backwards and forwards across the gap by means of ropes, or, when there is a good current, utilized as " flying bridges " (Sec. **90**). Free rafts are generally most easily moved by

towing; rafts with horses and vehicles cannot be rowed or poled, except under most favourable circumstances. The out-board motor is described in Military Engineering, Vol. III, Part II, Pamphlet No. 3.

2. *Rafts* consist normally of two piers connected by baulks on which the decking is laid; the length of each pier must be twice the width of the platform of the raft. Three-pier rafts, when loaded, are unmanageable in a stream and are not recommended. When loading a raft with infantry, the men should sit down on the edge of the raft as close as possible, and then the central part of the raft should be loaded.

If the raft consists of one pier only (such rafts may be constructed of barrels or logs) the central quarter only of the platform should be loaded.

Rafts of two or more piers are merely sections of a floating bridge; for the construction of barrel, steel drum, boat or log piers (*see* Sec. **91**); the decking is constructed in exactly the same way as a roadway; the lashings must be constantly watched.

3. *Log rafts* consist of one pier only; and are made in the same manner as log piers in a bridge.

4. The *deck space* required for rafts may be estimated from the following dimensions :—

TABLE 12.

	Length		Width	
	ft.	in.	ft.	in.
Armed man, sitting	3	6	2	3
Horse, harnessed	8	0	4	0
18-pr. gun	14	6	6	3
18-pr. limber *	5	9	6	3
L.G.S. wagon *	5	7	6	4
60-pr. B.L. gun (travelling position) ...	16	6	7	0
60-pr. limber *	7	0	7	0
Armoured car	17	0	6	6
Light tank	9	0	6	0
Medium tank	18	0	9	0

* Exclusive of pole.

5. When animals are carried, handrails must be provided, and screens are always desirable, but may have to be dispensed with in a wind.

6. *Landing stages and ramps.*—When rafts are used to ferry troops or transport across a river, the speed of operations depends largely on the landing facilities. These may consist either of (i.) landing stages or (ii.) ramps.

i. *Landing stages.*—Where there is no tide some form of trestle-pier landing stage is suitable. If there is a tide the pier will require a floating bay that can rise and fall with the tide. The connection between the raft and the floating stage must be improvised.

The service equipment can be used to form one or other of the types of landing stage shown on Plate **111.** The half floating bay of the folding boat equipment is an example. Similar landing stages can be readily improvised, or these landing stages modified to suit improvised rafts.

If landing stages already exist it will often be necessary to construct a floating pier of the same height as the raft in use, and connected to the fixed pier by a ramp.

ii. *Ramps.*—When embarking and disembarking personnel, if no landing stage exists, planks should be carried both for boats and rafts. For transport, hinged ramps that can be raised or lowered as required, may be provided on the raft. This method has the disadvantage that the ramps when raised are liable to catch the wind. The end loading raft of the folding boat equipment is an example.

Ramps, such as shown on Plate **120,** Figs. 1 to 4, may be used, but this method is slower than the above.

When loading or off-loading rafts up and down stream cables fastened to anchorages on shore, should be used to moor the raft as soon as it comes in. It is essential that this should be done effectively.

When loading vehicles on to rafts, particular care must be taken that the inshore pier does not ground (unless it is designed to be strong enough to do so), and that it does not become swamped. It is during the loading and unloading that the buoyancy of a raft is most severely tested, since the majority of the weight then comes on to one pier of the raft only. This may be overcome by the use of a ramp, the end of which is supported some distance in from the edge of the raft.

7. An *extemporized raft* to carry an 18-pr. field gun without limber or a weight not exceeding 24 cwt., may be constructed of four 20 ft. by 15 ft. waterproof covers stuffed with straw, as follows :—

Make a light framework of poles, 6 ft. square by 2 ft. 6 in. high, on the ground (a hole of similar dimensions will do almost as well). Then place two lashings about 24 ft. long across the framework each way, and over these the cover well soaked. Fill the cover with straw or similar material and trample it well down. The ends and sides of the tarpaulin are then folded over the straw, and the whole made into a compact bundle by securing the lashings across the top (Plate **112,** Figs. 1 and 2).

Two of these floats are then lashed together by means of two 14-ft. spars. This forms half the raft. The other half is made in a similar manner. The two halves are then lashed to one another, 3 ft. apart, by means of four 16-ft. roadbearers. The raft will then measure 15 ft. by 12 ft. by 3 ft. 6 in. In such a raft the buoyancy is greatly in excess of that actually required to carry the load, but this is necessary owing to the kind of material employed and the short length of the piers. With good covers the buoyancy will remain good for at least eight hours.

8. The stores required are :—

Covers, waterproof, black, G.S. 20 ft. by 15 ft.	4
Straw (tons)	1½
Planks	16
Spars (average 4-in. diameter), four 16-ft., four 14-ft., and two 12-ft.	10
Lashings, 1-in., about 3 fms. long	40
Lashings, 1½-in., about 6 fms. long	16
Ropes, 2-in., length according to width of river	2
Punting poles	2

Note.—Other sizes of covers included in the Vocabulary of Stores are :—

10 ft. by 6 ft. 12 ft. by 10 ft. 24 ft. by 18 ft.
30 ft. by 20 ft. 30 ft. by 30 ft.

9. Smaller rafts can be made in a similar manner by stuffing ground sheets with straw and placing them in a frame ; twenty-four of these made into a raft will support a load of 1,800 lb. (Plate **112,** Figs. 3 and 4).

10. An extemporized boat made of a bivouac sheet stretched over timber framing is shown on Plate **113.**

11. A light car or similar light vehicle can be floated in a waterproof cover. The following method is suitable. (*See* Plate **120,** Fig. 5.)

The cover (P.Q.R.S.) is laid out flat and the vehicle run on to the centre of it.

A lifting handle is then lashed to each hub of the car and a 1½-in. lashing is put through each lifting handle to act as a sling.

The car is eventually lifted with two 12-ft. spars, one across the bonnet and one across the back, the slings from the lifting handles passing round the spars. The length of the slings must be adjusted before the car is wrapped in the cover.

The cover is then folded up along the lines AA and BB with lashings passing across the top of the car. The cover is next folded along CC and DD and fastened with lashings passing from front to rear along the car. The corners are made into dogs' ears or folded along the sides of the car and held by a lashing passing round the car to corresponding dog's ear on the other side.

The limit to this expedient is the weight that can be lifted into the water and the size and condition of cover available. Care must be taken that no sharp projections pierce the cover.

12. Table 53 (p. 392) gives loads and dimensions of service light loads. Full tables are given in Military Engineering, Vol. III, Part I.

90. Permanent ferries

Rafts are difficult to row even in still water and, as this method of progress is slow it should be avoided for use with ferries.

Permanent ferries.—In the simplest form of permanent ferry, boats or rafts are hauled backwards and forwards from bank to bank by means of ropes stretched across the river. Such a rope should, if attached to the boat, etc., be made fast at the stem or stern, not amidships. Where the current is rapid and regular, a *flying bridge* may be used. This is a form of bridge in which the action of the current is made to move a boat or raft across the stream by acting obliquely against its side, which should be kept at an angle of about 55 degrees with the current (Plate **114,** Fig. 1). Long, narrow, deep boats with vertical sides are the best for the purpose, and straight reaches the most suitable places, as they are generally free from irregularities of current. A velocity of at least two miles an hour is required. It is necessary to have a vertical surface for the current to act against. If, therefore, the boat is a shallow one, or if the raft is made of casks or other material with a curved surface, vertical boards, called lee boards (Fig. 2), must be lashed to its side. These lee boards consist of two or three planks held together by battens nailed to them. The depth of the lee board must be kept to a minimum, as the action of the current on the lee board causes the raft to tilt ; a deep lee board may swamp the pier.

The cable, which should, if possible, float, can either be anchored in mid-stream or on shore at a bend of the river, and the raft can swing between two landing piers. The length of a swinging cable should be from one and a half times to twice the breadth of the river, and it will work better if supported on intermediate buoys or floats to prevent it from dragging in the water. A number of telegraph wires, buoyed as above, make a good swinging cable.

Another way is to stretch a wire cable across the river, and arrange for the raft to travel along it by means of a block with a large sheave. If the cable is under water the sheave should be attached to a buoy to lift it clear of the mud.

A spare anchor and cable must always be carried on the raft.

Further details for working flying bridges are given in Military Engineering, Vol. III, Part I.

91. Floating bridges

1. *Assault bridges.*—If the Kapok assault bridge is not available a bridge can be made up with petrol tins as in Plate **115.**

If properly constructed, these bridges are stable and a level roadway is ensured; they can be placed in position in a very few minutes by trained personnel.

The roadway consists of special light trench-boards with bearers arranged so as to interlock on the saddle of the float, and be pinned together.

To give the lateral rigidity so that the bridge can be boomed out rapidly across the river with a current, wire ties may be fastened from the end of the piers to the centre of the trench-boards on either side. Two men should be on the front end of the bridge; on reaching the far bank they will lay the shore bay and secure the mooring rope. Where there is little current one mooring rope passed through the rings on the ends of the piers, and made fast to the pickets on each bank, may suffice to hold the bridge in place; but additional mooring ropes, or anchors, will be needed where there is much current.

Casks or plank foot-bridges (Plate **116**) may often be useful but take rather longer to construct.

The Catamaran bridge (Plate **117**) is another useful type of light foot-bridge.

Approximate weights of component parts of some of the bridges described above, are as follows :—

		lb.
i.	Petrol-tin pier with saddle (Plate **115**)	110
ii.	Kapok pier with saddle	80
iii.	Pier of cask foot-bridge (Plate **116**)	350
iv.	Pier of single cask foot-bridge (Plate **117**) ...	220

2. *Other types of floating bridge.*—

i. *Floating piers.*—Each pier must have available buoyancy to support the heaviest load that may be brought on to one span of the bridge. The length of each pier should be twice the breadth of the roadway for the sake of steadiness, and with the same object, they must be connected together at their ends by tie baulks (Plate **118**). The waterway between the piers should never be less, and should, if possible, be more than the width of the piers.

ii. *Boat piers.*—Few boats, with the exception of heavy barges, are strong enough to allow of the baulks resting direct on their gunwales. A central transom should be improvised, by resting a beam on the thwarts, and blocking it up from underneath, so that the weight is brought directly on the kelson (Plate **121,** Figs. 1 and 2).

In a non-tidal river, the boats should be placed "bow on" to the current and slightly down at the stern: in tidal rivers they must be placed pointing up- and down-stream alternately.

Collapsible boats may sometimes be available. They should be used as described above, special care being taken that no weight comes on the gunwale. The weight varies according to size and make. They are usually about 6-ft. long and weigh about 200 lb.

iii. *Barrel piers.*—Piers of casks can be made up as shown in Plate **121,** Figs. 3, 4 and 5.

For a pier of seven 108-gal. casks the following are needed: *Gunwales*, 21 ft. by 4 in. by 5 in., slings of 2½-in. rope, 6 fms. long, with an eye splice 1 ft. long at one end, and a figure of eight knot 1 ft. 5 in. from the eye. For piers of 36-gal. casks, gunwales 9 ft. by 4½ in. by 3 in. are required.

iv. Large piers of small casks may be formed by first making piers of two to four casks (Plate **118,** Fig. 2); these are placed touching each other, and two baulks, which carry the roadbearers, are secured to their gunwales.

A pier of two rows of casks may be made. Two braces for each cask are first fastened to a baulk, and stretched out perpendicularly to it; the casks are then placed end to end on each side of the baulk, and over their own braces. On the cask are laid two gunwales, previously lashed together at the ends, and at two intermediate points, by lashings which have afterwards to be racked up; the distance from out to out of the gunwales should be less than a bung diameter. The braces are then secured to the gunwales by two round turns and two half-hitches. The four lashings connecting the gunwales are then racked, the two at the ends are secured to the baulks by lashings, which are racked up, and, finally, the pair of braces on each cask are laced together as tightly as possible, so as to counteract the tendency of the braces to slip over the ends of the casks. This can readily be done by the spare end of one brace on each cask after it has been secured to the gunwale, figure of eight knots being previously made in each brace to prevent the lacing from slipping upwards.

v. *Piers of tar or bitumen drums.*—The empty steel drums used for tar or bitumen and to be found in any road contractors' yard can be used in a similar way to barrels, for piers or rafts. Owing to the drums being cylindrical certain modifications are necessary.

The drums have to be set out at sufficient interval to enable the figure of eight knots on the brace to come between them. Alternatively the knots can be lowered, but this tends to make the brace loose. The process of " rock and heave " is not feasible and brace men have to tighten independently.

Plate **119** shows a raft of this type using forty drums designed for a 30-cwt. lorry. The lorry was loaded in this case by ramps made up in the form of wheel tracks (Plate **120**, Figs. 1 to 4).

Wire lashings can be used instead of cordage. Two pieces of No. 14 S.W.G. for slings are satisfactory. These are tightened up by braces of double wire, windlassed up tight, as in Plate **119**. The drums have corrugations on their sides which effectively prevent the slings slipping.

vi. When *log piers* are used, it is usually necessary to place the logs in two layers in order to give sufficient waterway between the piers; the logs are laid side by side, thick and thin ends alternating; they should then be strongly secured with ropes or dogs, and, if possible, by cross and diagonal pieces of timber fastened by spikes; a central raised transom must be used. The up-stream end of the pier may with advantage be slightly convex. Such piers are most easily put together and manipulated in the water.

3. *Tidal ramps.*—These will be necessary in tidal rivers, they are dealt with in Military Engineering, Vol. III, Part I.

4. *Method of building a bridge.*—A bridge can be put into position in the following ways :—

i. By *booming out*, *i.e.* when the head of the bridge already constructed is continually pushed out into the stream fresh materials being added at the tail. This method cannot be used with steep banks and deep water close in shore.

ii. By *forming up*, *i.e.* when material is continually added to the head of the bridge, the tail being stationary. This method is uninfluenced by the nature of the banks, no men being required to work in the water. Its only drawback is the distance the roadway materials have to be carried.

iii. By *rafting*, *i.e.* when the bridge is put together in different portions, or rafts, along the shore, each raft consisting of two or more piers, and these rafts are successively warped, rowed or towed into their proper positions in the bridge.

This method has the advantage that a large number of men can be employed simultaneously and, if secrecy be an object, the various portions can be constructed at some distance from the site of the bridge, and a favourable opportunity seized for its construction.

iv. By *swinging*, *i.e.* when the entire bridge is constructed alongshore, and then swung across the stream.

A long bridge can be constructed by a combination of two or more of the above methods.

5. *Anchors.*—As a rule, there should be an up-stream and down-stream anchor to every second pier of a floating bridge; in tactical operations under fire there must be an up-stream anchor to every pier.

For ordinary bridge work 56-lb. anchors, with a reserve of 112-lb. anchors, will generally suffice for moderate streams.

In the absence of anchors, or in a very rapid current, when the anchors are liable to drag or to pull the piers down by the head, a hawser (preferably wire rope) buoyed with floats can be stretched across the river (provided its width does not exceed 100 yards), and its ends secured to anchorages on each bank at a distance up-stream of about one-fourth the span; cables from the bridge piers are then secured to it. The danger of using this method under fire is that one shot may destroy the bridge.

6. *Protection.*—Arrangements must always be made, up-stream, for the protection of a bridge from damage by floating substances, either by a boat patrol or by posting men at each pier to pole off such floating objects into the fairway. Down-stream, rafts with buoyed floating ropes should be anchored to save men who fall off the bridge.

7. *Approaches.*—The *bridge ends* to floating bridges require careful consideration. In tidal rivers, and in non-tidal rivers, when the effects of droughts and floods may cause considerable variations in level, much ingenuity, time and labour are required in order that the bridge may be available at all times for traffic (*see* Military Engineering, Vol. III, Part I).

A floating pier should not be allowed to ground, as it will be liable to be crushed when a load comes upon it. If it has to ground, it must be built of large barrels and the bottom levelled, or a cradle made of reeds, brushwood or sacks of earth.

8. *Passage of traffic.*—If a bridge has to remain down for some time, arrangements may have to be made for the passage of river traffic. This can be done by having two or more rafts, at the centre of the bridge, arranged for forming " cut "; or the two halves of the bridge may be swung, to afford the requisite passage.

CHAPTER XIX

WATERMANSHIP

92. Boats and rowing drill

1. The following are the common technical terms used in connection with boats and their equipment, viz. :—

i. *Of a boat.*—The *bow* or *stem*, the *stern*, the *keel*, the *ribs* to which the planking is fastened, the *bottom boards* laid on the ribs at the bottom of the boat to prevent the ribs and planking being injured, the *thwarts*, or seats for the rowers, the *rowlocks* (in some boats *thole pins*, in others *crutches* are used): when not in use, the rowlocks are closed by pieces of wood called *poppets*; the *gunwale*, or upper plank of the boat's side: *painter* or rope fastened to a ring in the bow by which the boat is made fast to a mooring, etc. (in large boats painters used at each stern quarter are called *sternfasts*): the *rudder*, and *tiller* by which the rudder is moved. In light boats a *yoke* and *yoke lines* are substituted for the tiller. *Double-banked* boats are those, such as cutters and pinnaces, in which two rowers sit on each thwart: *single-banked*, such as gigs, whale-boats, and dinghies, have one rower on each thwart. The *starboard* side is that on the right hand of the coxswain as he faces the bow, the *port* side that on his left.

ii. *Of the oars.*—The *blade* is the flat part at the end, and the *loom* the part between the blade and the *handle*. Oars are said to be *shipped* or *unshipped* as they are placed in the rowlocks or laid in the boat, when their blades should be towards the bow. *Sculls* are short oars, used in pairs, *i.e.* one oar in each hand.

A boat may be *ahead*, *astern*, or *abreast* of another, or *abeam* when to one side, or on its *quarter* when astern to one side, or on its *bow* when ahead to one side. The rising tide is called the *flood*, and the falling tide the *ebb*. A vessel is said to be *moored* when it is made fast to a floating object secured by two or more anchorages.

2. The following is the proper equipment of boats :—

Equipment for ordinary ferry work

i. *Cutters*—

- One oar for each rowlock, including bow oars.
- One boathook for each side of the bows, laid in with hook forward.
- One short boathook for the stern, laid in with hook aft.
- One fender for each rowlock.
- One gangboard.
- One rudder.
- One tiller.
- One painter.

ii. *Wherries and other small boats*—

- One oar for each crutch.
- One boathook in bow.
- One fender for each rowlock.
- One rudder.
- One yoke and yoke lines.

Additional equipment for long journeys or rowing drill

iii. *Cutters*—

- One spare oar for each side.
- One bailer.
- One lifebuoy, with breastline attached.
- One anchor, cable, buoy, and buoy-line.
- One keg of water.

iv. *Wherries and other small boats*—

- One spare oar.
- One short boathook, in stern.
- One bailer.
- One lifebuoy, with breastline attached.
- One anchor, cable, buoy, and buoy-line.
- One keg of water.
- One gangboard.

3. *Manning a boat.*—With crews under instruction the instructor (coxswain) will fall in the crew in two ranks for double-banked boats, in one rank for single-banked, and number them. Nos. 1 are *bowmen* and the highest numbers are *strokes*. For double-banked boats the front rank will be *port oars* and the rear rank will be *starboard oars*. For single-banked boats the *odd* numbers will be *starboard oars*, the even numbers *port oars*.

The crew, while under instruction, will not be told off permanently to the places in the boat, but will each perform the work of bow oar and stroke oar in turn ; the N.C.O. in charge will keep a roster for the purpose—the stroke oars on one day becoming bow oars on the next day, and the stroke oars being taken by the men on the aftermost thwart but one.

" Man 1st (or 2nd) Gig (or Cutter)."

The boat-keepers bring the boat alongside, ship the rudder, and place the gangboard when necessary ; then the crew file into their places in the boat, and sit square on their thwarts, with their feet against the *stretchers* or *footboards*, which should be adjusted so that when the man is sitting upright the knees are slightly bent. The bowmen stand up, holding on by their boathooks. The others unship poppets, if necessary, and toss oars, taking care that the edges of blades are in the direction of the wind. The crew are then *proved*, if under instruction.

The usual way of *proving* (or ensuring that each man knows his number) is to call out the man's number, on which he should raise his left arm to the full extent above his head, and keep it there until the next number is called. The last man to be proved drops his arm on the command **" Down."**

When ready to start the coxswain gives the commands :—

" Shove off—Forward."

The bowmen shove off with their boathooks, and all hands get in their fenders.

" Down-oars."

On the command " Down—oars," which will not be given until the boat is clear, the men lift the oars till the handles are clear of their knees, allowing the blades to incline outwards and fall flat on the water together, taking care that the blades strike the water before the looms touch the gunwales : they then lay hold of the handles with both hands, backs up, thumbs round the handle, and place the oars in the rowlocks.

" Stand by to give way."

The men get ready to row, leaning forward, and extending their arms.

" Give way—all (or Port, or Starboard)."

The crew, or those named, give way together. The bowmen lay in their boathooks, sit down, and give way in time with the rest, taking care that they toss their oars and let them fall into the water together. The time of each stroke is taken from the port stroke oar. The oars should be dipped so as just to cover the blades, and in the return stroke they should be feathered by dropping the wrists and bringing the elbows close to the sides. The crew should not look at their oars except in rough water.

“ **Hold water—All** (or **Port,** or **Starboard**).”

The crew, or those named, hold the water, wrists slightly dropped, without allowing their oars to move either backwards or forwards.

“ **Back water—All** (or **Port,** or **Starboard**).”

The crew, or those named, back water together : this word should not be given without previously checking the boat's way.

“ **Stand by to lay on your oars—Oars.**”

This caution is given when it is necessary to stop rowing without laying in oars.

At the command “ **Oars,**” the crew complete their stroke and hold their oars feathered, at right angles to the boat. With proficient men this caution may be omitted.

“ **Stand by to toss oars—Toss oars.**”

For the purpose of saluting, etc., the oars are tossed by bearing down on the handles with the inner hand with a jerk, so as to spring the blades of the oars up smartly to the position of *Toss*, assisted by the outer hand. Oars are not tossed in boats fitted with crutches.

4. *Coming alongside a ship or landing on shore.*—Always go alongside head to wind or tide whichever is the stronger.

“ **Bows.**”

When the boat gets within 50 yards of the landing place the order “ **Bows** ” is given. Bowmen take one stroke after the order, toss oars together and lay them in. They then stand up in the bow of the boat with the boathooks vertically in front of them ready to fend off ; each man of the crew puts over his fender with his outer hand, continuing to row with the other.

“ **Way—enough.**”

This command is given when the coxswain sees there is sufficient way on the boat : the crew finish their stroke and row one more ; the port stroke then gives the command “ *Up*,” and all toss their oars.

“ **File—out.**”

All but the crew leave the boat.

“ **Lay in your—Oars.**”

The oars are laid, blades forward, between the men and their own side in a double-banked boat, and in the middle of it in a single-banked boat. To do this, the men keep their seats, but look towards the bow over their shoulders, as they lay them in quietly. The stroke oar next the landing stands with his boathook to hold the boat to.

Should there be a rough sea when the boat is alongside a ship or landing, the men sitting nearest will assist in keeping the boat from knocking against it.

With crews under instruction, or in case of difficulty in reaching the landing, the coxswain, instead of giving the command “ **Way enough,**” gives the caution “ **Stand by to lay on your oars,**” followed by the command “ **Oars,**” “ **Stand by to toss oars,**” “ **Toss oars,**” “ **Lay in your oars.**” The men lay on their oars, toss oars, and lay in their oars as above described.

5. *Gigs and boats with crutches coming alongside.*—When gigs or boats with crutches come alongside, the oars will be managed as follows : Bow oar will follow the commands given for cutters : the handle of each of the other oars is passed to the man on the next thwart forward, who hauls it through until the blade rests on its edge in the crutch, unless the oars are tied to the crutches, in which case they are allowed to swing. Occasionally the oars may have to be taken in and laid in the boat.

On leaving the boat each man returns the poppet into the rowlock, or takes the crutch in-board, as the case may be.

Boats are never to be left alongside a gangway, but as soon as the crew have got out the boatmen will bring the boat into its proper position. The tiller will always be taken out and laid in-board when the boat is not in use, and the back board and thole pins or crutches, if loose, will be removed.

6. *Instruction in cutter rowing.*

i. *Position of oars.*—Particular attention should be paid to this position before commencing practice.

Each member of the crew should be comfortably and squarely seated on his thwart with his heels together on the stretcher, toes turned out at an angle of about 45 degrees and back straight. The eyes should be directed on the man in front. The grip of the oar should be firm, but light, the fingers being over the oar and the thumbs underneath, the hands should be almost the width of the shoulders apart and the elbows kept into the side.

ii. *Pulling by numbers.*

" One."

(The position of " Stand by to give way.") The body is bent forward from the hips in a natural manner, keeping the back straight, knees apart, the arms extended to the full extent and the shoulders braced back ; the blade of the oar should be turned at right angles to the water, and about 1 ft. clear of it.

" Two." *

Raise the hands and drop the oar into the water until the blade is practically immersed, keeping it perpendicular. As soon as the blade is in the water the weight of the body is applied by driving with the legs against the stretcher, *keeping the back and arms straight,* until a position of the body is reached which is just past the perpendicular. On reaching this position, which is one from which the " recovery " is made by use of the abdominal and thigh muscles only, the arms bring the oar home to the chest by bending the elbows until the hands touch the breast—elbows kept close to sides—wrists arched.

" Three."

Drop the hands to clear the blade of the water and drop the wrists to bring the blade to the feather.

" Four."

Shoot the arms out to the full extent as smartly as possible.

" Five."

Swing the body slowly and steadily forward to position of " One," keeping the blade just clear of the water.

After the movements have been distinctly taught they should be combined as one, as early as possible. It should be impressed on the crew from the beginning that the five movements really constitute one even motion.

iii. *Hints to instructors.*—

(*a*) With a beginner teach " use of the body " first ; he can then be taught to apply extra power with his feet at the right time to increase the power and swing of the body.

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* If necessary split " Two " up into sub-numbers.
1. Raise hands, drop blade into water.
2. Commence stroke, pull through.
3. Bring hands to chest, bend elbows.

(*b*) A man should be taught to consider his arms as merely connecting rods between the body and oar. The use of the biceps in rowing should be discouraged.

(*c*) See that the distance of the swing back is limited to a position from which the body can be recovered by use of the abdominal and thigh muscles alone. Any excessive swing back will develop a tendency to recover the body by pulling up on the oar. The swing must be slow and balanced and exactly in the fore and aft line. Any tendency to rush the swing must be checked as it will cause raggedness at the beginning of the next stroke. As the body swings the hands should at the same time be stretching and reaching out as if constantly striving to touch something which is constantly receding.

(*d*) The oar must not hang at the chest. The hands must come away quickly otherwise it will be necessary to rush forward in the swing to make up lost ground.

(*e*) *Recovery.*—This is largely dependent on the abdominal muscles and these must be exercised and developed to obtain an elastic recovery.

The first part of the recovery should be the most rapid.

(*f*) *Catch.*—The beginning of the stroke should be the most forcible part. This " catch " should be driven from the body as if the weight were to be lifted off the seat by the joint support of oar and stretcher. Avoid striking the water in the catch.

(*g*) *Distance of swing back.*—This should be limited to a position from which the body can be recovered by the use of the abdominal and thigh muscles alone. An excessive swing back will develop a tendency to pull up on the oar.

(*h*) *Faults to guard against.*

Finishing with the biceps instead of the muscles behind the shoulders. Result—elbows stuck out.

Faulty grasp of the oar.

Overreaching with the shoulders instead of with the shoulders braced.

Rowing deep at the finish, arising from the use of the arms only.

Screwing from one side to the other.

Uneven swing forward, due to sluggish or early recovery or misuse of the muscles.

Faulty time, due to rushing forward or not keeping the eyes in the boat.

Not rowing the stroke home, due to weakness or from the cramped attitude at the finish or an overreach, or to the oar being taken out of the water too soon.

Fouling the water going forward. Due to too short a stretcher or to the hands not dropping sufficiently at the finish of a stroke or not shot out quickly enough from the chest.

Bending the arms too soon.

Want of catch is a want of knack of using power at the right time.

The stroke when once caught must be held, drawing it right through.

(*i*) Teach through the eyes, *i.e.* demonstrate.

(*j*) The rhythm should be about 30 strokes to the minute in cutter rowing.

(*k*) After a certain amount of proficiency has been attained, let the crew practice; the eye to guide the beginning of the stroke, and the ear the finish.

Remember that on a very dark night it would be difficult to "watch the man in front"; therefore, to judge the ear should be trained to recognize the rhythm of the loom in the rowlock.

(*l*) Avoid generalities in coaching; it is better in correcting faults to pick out and address individuals.

(*m*) Note how each pupil progresses periodically, and inform him.

(*n*) Insist on discipline in a boat; the man in charge of a boat is responsible for the safety of crew and boat; therefore he must not be afraid to exercise his responsibility, and do as he thinks and not as others suggest.

(*o*) Trace faults to their origin, distinguishing between cause and effect: defects in gear may cause bad pulling.

7. *Breastlines* are 10-fm. lengths of 1½-in. tarred cordage, and are carried in pontoons, rafts, etc. They are used for the purpose of warping a pontoon or raft into bridge, passing a towing or mooring cable, etc.

To throw a breastline one end of which is made fast to the pontoon or raft or to a heavy cable, coil the line in the left hand from the fixed end. Pass sufficient coils to the right hand to give a suitable weight for throwing. Stand firmly with feet well apart and throw the coils in the right hand in the required direction with a horizontal sweep of the arm Allow the coils in the left hand to run off evenly. Do not drop the coils from the left hand or they will become tangled.

Do not swing the coils in the right hand before casting as this will usually result in a poor cast.

8. *Precautions to be taken.*—The following precautions will be taken by all parties employed on the water:—

i. In order to prevent injury, boats are always to be moved on shore on an *even keel*, and pontoons should be carried, not dragged.

ii. Cables, when on board, are always to be properly coiled with the running ends on the tops of the coils, and the anchors laid clear of the coils: boats' anchors should be examined before starting, and when in the boat should be *unstocked*, and lying on the bottom forward, unless when likely to be wanted for immediate use.

iii. While rowing, the men are always to face the coxswain.

iv. When bringing a boat to moorings, or to a pier, always come up against the tide or wind, whichever is the stronger; and when coming alongside a vessel, whether at anchor or under way, bring the boat's head in the same direction as that of the vessel.

v. When a large body of men is to be carried in boats they should all be told off in a column of boat-parties, with the water on the directing flank. The crews being in their places, the boat-parties get the order **"File-In"**: each party forming single file as it reaches its boat. The men should be made to sit down on the thwarts outside the rowers, so as to *trim* the boat, and if necessary *double man* the oars. No man is to sit on the gunwale, or on any occasion to stand up, unless ordered.

vi. In selecting anchorages, care should be taken to avoid casting the anchors among mooring chains, or other obstructions.

vii. Stores should not be thrown ashore; everything should be handed or laid down carefully.

viii. Men are not to jump into the water without orders. Special men should be told off to perform any work in the water.

ix. When towing with more than one boat or raft the heaviest one is to be nearest the load, and a boat moderately loaded is better to tow with than one quite light. When a large boat tows a small one, any load is best carried in the former. The tow-line should be made fast to the sternmost ring on the kelson or internal keel and not to the ring on the sternpost, and the towing boat can then be steered by pushing the tow-line over her quarter on the side to which it is wished to turn. Short tow-lines are generally best, and the boat in tow should also be steered. Rafts should be towed with two tow-lines. A boat taking another in tow, passes it, keeping her oars clear of the other, places herself right ahead in line, and gives way as soon as practicable after the painter or tow line has been passed from one to the other. A boat should not give another boat or raft her painter, until she is in line ahead of her, and special care must be taken to keep the two clear of each other, so as not to lose the power of rowing.

9. *Saluting*.—The following are the rules for saluting to be observed in military boats (*see* also King's Regulations) :—

i. When an officer is in the boat :—

Rank of officer in boat (1)	When passing (2)	Under oars (3)	Meeting at landing place or alongside ship (4)
i. Field officers	Flag, or general officer, or Marshal of the Royal Air Force.	" Lay on Oars," Officer salutes.	Crew " Eyes Front." Officer and coxswain salute.
ii. Field officers	Other naval, military, and air force officers, if senior.	Officer salutes.	Officer salutes.
iii. Officers below rank of field officer.	Flag, or general officer, or Marshal of the Royal Air Force.	" Toss Oars," Officer salutes.	Crew " Eyes Front," Officer and coxswain salute.
iv. Officers below rank of field officer.	Commodore Captain Commander Brigadier. Colonel. Lieutenant-Colonel. Air Commodore, Group Captain, Wing Commander.	" Lay on Oars," Officer salutes.	Crew " Eyes Front," Officer and coxswain salute.
v. Officers below rank of field officer.	Other officers of the other services whom they know to be senior.	Officer salutes.	Officer salutes.

ii. When no officer is in the boat :—

When passing (1)		Under oars (2)	Meeting at landing place or alongside ship (3)
i. Flag officer Commodore	General officer Brigadier. Marshal of the Royal Air Force, Air Commodore.	" Toss Oars," coxswain salutes.	Crew " Eyes Front," coxswain salutes.
ii. All other officers ...	...	" Lay on Oars," coxswain salutes.	Crew " Eyes Front," coxswain salutes.

Note.—In boats fitted with crutches oars are never to be tossed, but the salute should be given by laying on oars.

iii. In steam and motor boats engines are to be stopped where, in pulling boats, oars would be tossed ; engines are to be eased where pulling boats would " lay on " oars.

iv. Laden boats, or those towing or in tow, are not to toss or lay on their oars.

v. Coxswains of boats under oars or sails when an officer is in charge only salute at landing places.

vi. Salutes in boats under oars or sails are to be made sitting down, in other cases standing up.

vii. Boats laying off on their oars are to salute as above, but the bowmen will salute as well as the coxswain.

viii. Boat keepers salute standing up in the ordinary manner.

ix. For a Royal Salute the crew toss oars and stand up (in double banked boats only).

x. When a general officer is saluted with guns he will, on the first gun being fired, if in a steam boat, have the engines stopped, or, if in a pulling boat, give the order " lay on oars," and on the last gun being fired will turn towards the ship and salute.

10. The **" rule of the road "** afloat is :—

i. Rowing boats give way to all other traffic.

ii. Steam boats give way to sailing boats.

A steamer gives notice of an alteration of course by blasts of her whistle as follows :—

1 blast—" I am altering my course to my right."
2 blasts—" I am altering my course to my left."
3 blasts—" I am going astern."

93. Anchors

1. *Parts of an anchor*.—The *flukes* of an anchor are the parts that hold the ground ; the *crown* is the part midway between the flukes ; the *shank*, the *stock*, the *washer*, and *key* for keying the stock to the shank, and the *ring* (Plate **122**).

To *cast* anchor is to heave it overboard, while to *weigh* anchor is to raise it from the bottom.

2. *Making up anchors for casting*.—Anchors must be properly stocked and keyed. The cable will be carefully coiled down, one end being made fast to the anchor ring with a fisherman's bend, leaving 3 ft. of running end. The buoy must always be attached to the anchor on shore. One end of the buoy line will be made fast with a split clove hitch over the crown of the

anchor and finished off with two half hitches round the shank; the other end of the buoy line will be made fast to the ring at either end of the buoy with a fisherman's bend (Plate **122**, Fig. 1).

3. *Placing anchors on boats.*—The greatest care must be taken that cables are not kinked when placed on the boat; to ensure this, the coil must be carefully lifted horizontally by two men, working together, and laid flat in the boat or on the deck of the pontoon.

After this has been done the anchor buoy and buoy-line will be placed on top of the cable.

4. *Casting.*—Anchors will be cast from the boat or pontoon as follows:—

On the command "**Prepare to Cast**" from the N.C.O. in charge the anchor man will place the ring of the anchor on the gunwale, with shank vertical and crown uppermost. He will hold the anchor with one hand by the shank just below the crown, and with the other hand he will take up the buoy. On the command "**Cast**" the anchor man will push the crown away from him and allow the anchor to fall into the water. He will then throw the buoy overboard and stand by to pay out as required.

In strong streams, when laying upstream anchors from a boat or raft, it is sometimes convenient to lay one above the line of upstream anchors; by means of this the anchor-boat party can drop downstream to the bridge without fouling it, and after handing on a cable can haul up against stream each time it is about to lay another anchor, the downstream boats or rafts being similarly helped by cables from the bridge. In large bridging operations, one or more reserve anchor boats or rafts should be kept ready moored upstream.

In the absence of anchors, a hawser can be stretched across, buoyed with floats, and its ends secured to anchorages on each bank at a distance upstream of about one-fourth the span; cables from the bridge piers are then secured to it; or these cables may each be secured ashore as far up-, or down-, stream as possible.

5. *Belaying cables to piers.*—Anchor cables will be belayed to the pontoon cable bollard with a turn round the bollard and a figure of eight, both for temporary and permanent belaying.

6. *Tripping anchor.*—Anchors are commonly raised by the buoy-line (or *tripping-line*), but it may sometimes be necessary to use the cable by hauling it in till the boat's bow is well down; the cable is then secured and the men move to the stern and force up the bow and with it the anchor. Weak boats will not, however, stand this.

7. *Anchors in kedge.*—In a strong current it may sometimes be necessary to use two anchors in kedge. They are made up as on Plate **122**, Fig. 1. A buoy must be attached to each anchor. The distance apart of the anchors must be greater than the depth of the stream or it will be difficult to weigh the anchors as they will both come up at once.

8. *Improvised anchors.*—In bridging operations on a large scale, it is often necessary to improvise temporary anchors to moor the rafts, boats, etc.

A form of anchor used frequently in India is a net filled with stones. This has been found to hold on river bottoms covered with boulders where nothing else held.

An anchor may be made of two picks lashed together in two places, and two other pick-heads fitted over their ends, which are prevented from slipping off by two light lashings. It is difficult to select picks that will fit firmly together for this anchor and it will probably be necessary to bend one of the points (Plate **122**, Fig. 2).

Another anchor consists of one pick, the handle of which is rounded just below the head, and another pick-head driven on the handle at right angles to the first, and wedged there by driving two spike nails. The holding power of this anchor is much increased by lashing sand-bags filled with stones to the head (Plate **122**, Fig. 3).

Any of the above anchors could be made by a couple of men in fifteen minutes.

A cask with six or eight projecting stakes run through holes bored diametrically near the bottom, and filled with stones, forms a good anchor, the cable being secured to the stakes inside the cask.

Rails or chairs from their weight answer instead of anchors; rails bent into the form of a grapnel are very powerful.

A form of wooden anchor which has been found useful is shown in Plate **122**, Fig. 4, the crown being weighted with chains, etc.

Wicker anchors (inverted funnels) with a content of about 15 cu. ft., are found to hold well when filled with stones.

Another anchor (Plate **122**, Fig. 5) that has been much used on rocky bottoms, consists of a cross formed of two pieces of wood 5 in. by 3 in., and 3 ft. long, halved into each other with the ends pointed. Into each arm, 8 in. from the point, a stake 6 ft. long and 2 in. in diameter is wedged. In the framework thus formed heavy stones or shot are placed, sufficiently large not to slip out of the frame, and the four stakes are secured together at the top by two lashings.

A pair of wheels, lashed with their felloes together, and the space between the spokes filled with stones, makes a good holding anchor; or a stone with a ring for a cable is convenient. The cable should not be lashed round the stone, as the edges are likely to fray the rope and cut it through in time

A harrow loaded with stones, wooden cases, or gabions, filled with stones may also be used in an emergency.

PART IV—ROADS. TRAMWAYS. RAILWAYS

CHAPTER XX

ROADS

94. Roadwork in war

1. For the movement of modern armies good roads are essential and these must be kept in a good state of repair.

2. Roadwork in a theatre of operations may be divided into :—

i. Provision of new roads.
ii. Improvement of existing roads into wider and better surfaced roads.
iii. Provision of temporary roads or tracks for use during some phase of operations.
iv. Maintenance of existing roads and tracks.

3. The military engineer must, therefore, have a knowledge both of the construction and maintenance of permanent roads and the construction and maintenance of war time expedients suitable for any country or climate.

4. The following sections are designed to assist the R.E. N.C.O. to carry out efficiently the practical work on roads that he is likely to be called upon to supervise. The theory and design of roads is dealt with fully in Military Engineering, Vol. V.

95. Drainage and earthwork

DRAINAGE

1. Road drainage is vital to the success of a road. The parts that require to be drained are :—

i. The ground in the vicinity.
ii. The formation.
iii. The foundation.
iv. The surface.

2. *The drainage of the ground in the immediate vicinity of a road* and also the collection and disposal of the water from the formation, foundation and surface is carried out by two longitudinal drains or ditches, one on each side of the road (Plate **123,** Fig. 1).

Dimensions: $2\frac{1}{2}$ ft. to 3 ft. in depth, the bottom being at least 1 ft. below formation level. Width: 1 ft. 6 in. at bottom, width at top depending on angle of repose of soil. Sides revetted if necessary. Distance from edge of road: at least 6 ft., if they have to be nearer a slab or pipe drain may be constructed and covered with stones or brushwood. These are known as " blind " drains (Plate **124**).

Catch-water drains are used to intercept the water from the uphill slopes of cuttings and on sloping ground and are cut on the uphill side of the road; they are in addition to the side drains (Plate **125**). They should discharge into the nearest watercourse and be connected to the side drains at intervals.

3. *Drainage of the formation.*—A subsoil of sand, gravel or chalky nature or a rock formation will not require drainage. With an impermeable clay subsoil water will not drain off and transverse drains must be cut in the formation and connected with the side drains. They should be laid **15** to **18** in. below the formation with a fall of about 1 in 50. Their distance apart will vary from 12 to 20 ft. in heavy clay, to **50** ft. in lighter clay (Plate **126**). These drains should be filled with large stones, brushwood or agricultural pipes.

4. *Drainage of foundation.*—A foundation of large stones will allow any water to percolate through to the foundation and thence to the side drains.

5. *Drainage of surface.*—Water falling on the surface runs off into the side drains, by means of the camber given to the road surface.

Camber is required for the purpose of drainage. The rougher the surface the steeper the camber should be. Too great a camber causes skidding and makes traffic hug the centre of the road.

The usual amounts are :—

Nature of surface	*Camber*
Gravel	1 in 24
Water bound macadam	1 in 30
Tar or bitumen bound macadam ...	1 in 40
Stone setts	1 in 40
Wood paving	1 in 40
Asphalt	1 in 40
Concrete	1 in 60
Brick paving	1 in 48

On curves, for fast moving traffic, camber should be changed to *superelevation, i.e.* the outer side of the road is higher than the inner. A rough rule is as follows :—

i. On curves of 300 ft. road or less— $\frac{3}{4}$ in. a ft. width.
ii. On curves of 300 to 1,000 ft. $\frac{1}{2}$-in. a ft. width.
iii. On curves over 1,000 ft. keep normal camber.

6. *Culverts* and bridges are required to carry the cross streams under the road and the surface water that collects on the upper side of the road. Spans up to 12 ft. are called culverts, above 12 ft. they are bridges.

They are of the following types :—

i. *Pipe culverts* for spans of from 2 to 4 ft. The pipes may be of stonework up to 2 ft. in diameter, of concrete or cast iron up to 4 ft. in diameter (Plate **127**), or corrugated galvanized iron pipes surrounded by concrete.

Constructional points :—

(*a*) They should be buried on 6 in. of concrete and if under heavy embankments surrounded by 6 in. of concrete.
(*b*) Each end must be suitably protected and supported by a head wall.
(*c*) Water must not be allowed to find its way to the outside of the pipe.
(*d*) The pipes must be laid with an initial camber to allow for settlement; 1 in. for every 5 ft. of vertical bank is suitable.
(*e*) Joints must be well filled and caulked with cement.

ii. *Slab culverts* providing up to 15 or 20 sq. ft. of waterway may be constructed of roughly squared stones laid dry or in cement and spanned by a stone slab. *See* Plate **127** for constructional details. Reinforced concrete slabs are suitable for larger spans (Plate **128**).

iii. *Arched culverts* may be used for spans of 5 ft. or more. If the fill above the culvert is small a slab culvert is better.

iv. *Box culverts.*—For hasty work in war rectangular wooden boxes up to 3 ft. × 3 ft. in section may be made (Plate **129**). They should be well creosoted before placing.

EARTHWORK

7. *Clearing.*—The necessary width on each side of the centre line is cleared of all trees, bushes or other vegetable matter. When tree stumps are to be grubbed the trees are usually cut above, but not more than 3 ft. from the ground. If the stumps are to be left the trees are usually cut at ground level.

8. *Spitlocking and slope stakes.*—The outer edges of the

earthwork are then marked on the ground. This is done by pegs driven on either side of the centre line at intervals of 100 ft. and connected by longitudinal spitlocking. Where there is no appreciable cut or fill, the pegs will form two lines parallel to the centre line, and the width of the formation apart. Where the amount of cut or fill is appreciable these lines will be farther apart to allow for the slope of the side of the cutting or embankment. In such cases the pegs are referred to as "*slope stakes*" or "*batter pegs*."

Slope stakes may be set out in the field without any plotting by the following method :—

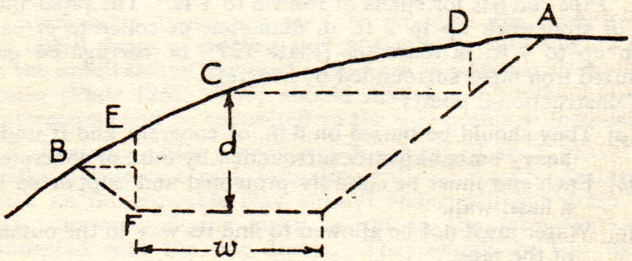

FIG. 3.

Assume a cross-section as shown above (Fig. 3), C is the centre line peg, d is the depth of the cutting and w the width of the base ; the side slopes are 1 in 1. The problem is to locate A and B.

To locate A. D is a point $\left(\frac{w}{2} + d\right)$ from C. By trial and error (with level, staff and tape) find a point such that its height above C will equal its distance outside D. This will be A.

To locate B. E is a point $\frac{w}{2}$ from C. By trial and error find a point such that its height above F will equal its distance outside E. This will be B.

The procedure is exactly similar in principle for side slopes of 1 in $1\frac{1}{2}$, etc., and for a bank (the figure being reversed).

9. *Grubbing.*—The space required for the road, berms and side drains is cleared by grubbing all stumps and vegetable matter. In fills over 3 ft. in height it is unnecessary to remove stumps that are cut flush with the ground.

Stumps may be removed by digging, pulling, burning, blasting or a combination of these methods. Burning and digging are slow methods. When the stumps are few and scattered, pulling is a rapid method. This can be done with traction engines, tractors or animals. For the removal of large scattered stumps explosion is the most rapid and economical method. The stumps are split by explosive and the remains pulled.

10. *Grading.*—The heavy earthwork can then be started. Embankments are made from the spoil out of the cuttings or from borrow pits, care being taken that allowance is made for shrinkage of the soil in embankments.

11. *Ditches and drains.*—As soon as the grading approaches completion the drains in the formation, if required, should be laid and the necessary ditches and catchwater drains dug.

12. *Formation.*—After the rough grading of the alignment is done the formation is excavated out to the required width of the foundation. Embankments should be given as long as possible to settle. It is essential to have substantial berms or shoulders so that when the foundation is rolled it will be compacted and not merely spread out. These shoulders are formed by removing the earth from the middle of the roadway and grading it to the sides, thus forming a trench for the stone foundation. The depth at the edges should equal the total thickness of the foundation and the surface coat.

The excavation must be done with care so that no uneven places occur and, if soft or yielding places are encountered, the soft material should be removed and hard substituted. In all cases the formation must be thoroughly compacted by the use of a heavy roller. On a clay subsoil a layer of at least 6 in. of clinker, ashes or sand should be added and rolled to act as a seal. The formation is made with the camber required in the finished surface.

13. *Cuttings and embankments.*—

i. In excavating for a *cutting* without the use of mechanical excavators, the most convenient method is to dig small trenches along the cutting lines at ground level on each side, and to take off the soil in layers of about 1 ft. in depth, commencing each layer 1 ft. nearer the centre line. By this means the sides of the cutting will be formed in steps which can be dressed to the required slope when formation level is reached. The turf and top spit of soil should be placed to one side for re-use later in facing the berms and slopes. A gentle gradient is given to the road throughout the length of a cutting for the purpose of surface drainage.

If the spoil cannot be used in a neighbouring embankment a spoil bank must be formed on low ground away from the cutting. Spoil must not be dumped on the slopes above a cutting or it will cause slipping of the sides.

ii. *Embankments.*—Borrow pits must be resorted to if material from a cutting is not available. They must not commence within 10 ft. of the toe of the bank.

When constructing an embankment profiles of lath and spun-yarn should be set up at about every 50 ft. These should be of the finished section plus an allowance for settlement. This may vary with different soils from 1 in. to 1½ in. for every foot of height.

In low embankments, up to 5 ft. in height, it will suffice to remove all rubbish, roots and vegetable matter, but with high ones it may be necessary to remove the top soil and to put a foundation of sand or gravel.

The earth should be placed on the site in successive layers of from 1 to 2 ft. thick and thoroughly rolled or rammed. Layers should slope inwards and the central portion should be filled last. In no case should the material be tipped along the centre and spread outwards.

In making an embankment on side-long ground the difficulty is to prevent the material from slipping down the hill. The natural slope beneath the embankment should be stepped or benched (Plate **130**, Figs. 1 and 2).

iii. *Retaining walls* built of stone either dry or laid in mortar, brick or concrete may be needed to hold up the toe of the bank and to prevent slips of the hillside above. Details are given in Military Engineering, Vol. V.

On steep slopes the whole of the roadway should be on firm ground, but this will involve additional labour in the excavation and heavier walls (Plate **130**, Figs. 3 and 4).

In repairing the slope of an embankment that has slipped, the old earthwork slope should be stepped before fresh earth is thrown on.

96. Permanent road construction

MACADAM ROADS

1. *Principles of construction.*—A macadam road consists of a *foundation* of large 10-in. to 12-in. stones of a durable nature, on which is laid a *surface* of smaller hard stones 3 to 4 in. thick. This is *bound* together by either water, in which case it is called water bound macadam, or tar, bitumen or bituminous emulsion, when it is called tar or bitumen bound macadam. Upon the surface coat a *surface dressing* is usually applied of tar or bitumen sprayed on the surface and gritted with chippings which are immediately rolled in. This serves the double purpose of sealing the road against penetration of moisture and providing a wearing surface which can be

TABLE 13.—SHORT SPECIFICATIONS FOR DIFFERENT TYPES OF MACADAM ROAD

Type of road (1)	Surface coat (2)	Method of binding surface (3)	Sealing coat (4)	Remarks (5)
1. Water bound macadam.	Hard broken stone of specified gauge. If granite or similar hard stone use :— 60 per cent. 2-in. stone 30 per cent. 1½-in. stone 10 per cent. 1-in. stone If soft stone 60 per cent. may be 2½-in. stone. Spread evenly on foundation to depth of 4 to 4½ in. for 3 in. finished coat. Roll dry with 8 to 12-ton roller until firm.	After dry rolling spread with chippings or screenings and water. Roll until consolidated. Not more than 4 gals. water per sq. yd. preferably 2 gals. Never use earth for binding.	After surface is dry sweep off all dust and spray or pour either *tar* at 240° F. 1 gal. to 4 sq. yds. *bitumen* at temp. specified by makers, 1 gal. to 4½ sq. yds. or *emulsion*, cold, 1 gal. to 4½ sq. yds. For new roads in two coats :— 1st coat—2 gals. to 5 sq. yds. 2nd coat—1 gal. to 5 sq. yds. Blind with chippings as follows :— If tar or bitumen used—½ to ¾-in.—1 ton per 130 sq. yds. If emulsion used—½ to ¾-in.—1 ton per 100 sq. yds. each coat. Roll with 6-ton roller immediately.	—
2. Tar or bitumen grouted macadam.	Clean hard stone gauged from 2 in. to ¾ in. spread and rolled as above.	When applied *after* rolling heat tar or bitumen in boilers or tanks, tar at 250° F. Bitumen as specified (275° to 400°). Pour or spray at rate of 1 gal. per sq. yd. While still warm apply clean dry ¾-in. chippings at rate of 1 ton per 100 sq. yds. When applied *before* rolling. As above, but lightly roll before spreading chippings. Then spread chips so as to fill voids in surface. Roll in both cases until consolidated.	Seal with the tar or bitumen used in consolidation, at rate of 1 gal. per 4 sq. yds. and ¾-in. chippings 1 ton per 130 sq. yds.	—
3. Bituminous emulsion grouted macadam.	As in 2 above.	Pour or spray emulsion at rate of 1½ to 2 gals. a sq. yd. for a 3-in. surface. ½-in. chippings are *immediately* spread at rate of 1 ton to 100 sq. yds. The surface is then rolled to fix chips and again on following day. Traffic is then allowed on.	After a few days seal with emulsion at rate of 1 gal. to 4 sq. yds. and ¾-in. chippings at rate of 1 ton to 130 sq. yds.	—
4. Tar—or bitumen—macadam. (Pre-coated.)	Stones gauged as above already coated with tar or bitumen by special machinery are brought to site and spread and carefully raked over foundation to specified thickness and rolled with 8-ton roller.	Bind with pre-coated ½-in. chippings at rate of 1 ton per 130 sq. yds. Roll with light roller.	Surface dressing as in 1, above.	*Tarmac* is similar, but is made with blast furnace slag pretarred. "Tarmac" is a trade name only applicable to this type.
5. Bituminous emulsion macadam. (Pre-coated.)	Similar to above, but with emulsion. Usually laid in two courses, a binder course and a wearing course (composed of smaller aggregate). Rolled together with 6 to 8-ton roller on two consecutive days.	—	Surface dressing as in 3, above.	—

Table 13.—Short Specifications for Different Types of Macadam Road

Type of road (1)	Surface coat (2)	Method of binding surface (3)	Sealing coat (4)	Remarks (5)
1. Water bound macadam.	Hard broken stone of specified gauge. If granite or similar hard stone use :— 60 per cent. 2-in. stone 30 per cent. 1½-in. stone 10 per cent. 1-in. stone If soft stone 60 per cent. may be 2½-in. stone. Spread evenly on foundation to depth of 4 to 4½ in. for 3 in. finished coat. Roll dry with 8 to 12-ton roller until firm.	After dry rolling spread with chippings or screenings and water. Roll until consolidated. Not more than 4 gals. water per sq. yd. preferably 2 gals. Never use earth for binding.	After surface is dry sweep off all dust and spray or pour either *tar* at 240° F. 1 gal. to 4 sq. yds. *bitumen* at temp. specified by makers, 1 gal. to 4½ sq. yds. or *emulsion*, cold, 1 gal. to 4½ sq. yds. For new roads in two coats :— 1st coat—2 gals. to 5 sq. yds. 2nd coat—1 gal. to 5 sq. yds. Blind with chippings as	—
	8-ton roller.			plicable to this type.
5. Bituminous emulsion macadam. (Pre-coated.)	Similar to above, but with emulsion. Usually laid in two courses, a binder course and a wearing course (composed of smaller aggregate). Rolled together with 6 to 8-ton roller on two consecutive days.	—	Surface dressing as in 3, above.	—

renewed at small cost before the surface has begun to disintegrate. Plate **123,** Fig. 2, and Plate **131,** show typical cross-sections of modern macadam roads.

2. *Foundation.*—10 to 12-in. stones are laid by hand with widest edge downwards and greatest length across the road, the stones should break joint. Stones are bound by inserting and driving smaller stones to wedge them into position. All projecting points are broken off with a sledge hammer. Small interstices are filled with chippings. The foundation is then rolled with a heavy roller until all stones are firmly bedded and none move under the roller. All depressions are filled with stone chips not larger than 2 to 3-in.

Rolling should be carried out by starting at the kerb and rolling once over the full length to be done. On the return journey the roller is turned inwards sufficiently to enable the outer rear wheel just to overlap its previous track, and so on until the centre line is reached. The process is then repeated starting from the other kerb. The cross-section of the surface should be frequently checked with the templet. (*See* Plate **132**.)

Substitutes for stone as a foundation are broken brick, clinker and other similar material.

This foundation is common to all macadam roads.

3. Table 13 shows in tabular form the specification of the various types of macadam road in present-day use.

Reinforced Concrete Roads

4. Concrete construction is dealt with in Chapter VII. The design of concrete roads is contained in Military Engineering, Vol. V.

The following paragraphs outline the chief practical points in their construction.

5. *Plain concrete* makes good roads over rock or hard gravelly soils. It is not suitable over clay or other easily compressible soils. In order to obtain a key for the foundations the formation should be made or left rugged in the case of rock, and in other cases it should be trenched at intervals of not more than 6 ft. in both directions, the trenches crossing each other and being 9 in. wide and 6 in. deep.

6. In *reinforced concrete* slab roads the formation should be drained as for other types of roads. If the soil is very bad two or three inches of hard core or cinder should be well rolled in. For soil of better quality the top soil is removed, and the formation well rolled. A layer of tough waterproof paper is laid before placing the concrete. Paper cement bags are suitable.

The concrete slab, usually 5 to 8 in. thick is either singly reinforced near the top surface, or, in the best class of roads doubly reinforced. The reinforcement is made up of either special welded reinforcement mesh, expanded metal or a mesh of steel bars wired at each crossing.

Owing to stoppages of work and cracking due to shrinkage, reinforced concrete roads cannot be laid in one continuous length. The road is therefore divided into bays separated by joints. Plate **133,** Fig. 1, shows a " continuity bar " method of making a joint. Fig. 2 shows another type. There are many special types in use. The bays, usually 40 to 50 ft. long and 10 to 15 ft. wide are usually laid alternatively for a considerable length of road and when these have set the remaining ones are laid. The ends of the first sections should be painted with bitumen to prevent adhesion.

The spaces between sections are afterwards filled with hot bitumen.

7. *Construction notes.*—

i. After the formation has been prepared the forms shown on Plate **134** are placed with their top edges accurately levelled to the finished level of the top of the concrete.

ii. The concrete is usually laid in two layers of different quality concrete, the top course being laid before the bottom course has taken its initial set in order to form one homogeneous mass.

iii. Lay the bottom layers of reinforcement supported on distance pieces 1½ in. high and place bottom course of concrete flush to reinforcement level. The distance pieces, made from ½-in. steel bars, are shown on Plate **135**, Fig. 2. The dimensions *x*, *y* and *z*, depend on the size of the mesh, the height at which it is to be held, and the length required for stability, respectively.

iv. Place distance pieces to form support for top layer of reinforcement ; place bottom course of concrete to finish flush with the tops of these distance pieces and tamp thoroughly with tamper shown on Plate **134**, Fig. 3.

v. Lay second layer of reinforcement.

vi. Lay the top course of concrete and tamp thoroughly with tamper shown in Plate **134,** Fig. 3. Finish surface with finishing board (Fig. 1), care being taken to keep adjoining slab ends truly level with the aid of the straight-edge (Fig. 4) for traverse joints and the templet (Fig. 5) for the longitudinal joints. These processes must follow immediately one after the other and gangs must be organized to work in échelon (Plate **135,** Fig. 1).

vii. When concrete has taken initial set, and is not too hard to be worked, but sufficiently hard to take a tooled finish, the edging tool (Plate **134,** Fig. 6) should be run round all arrises to round them slightly.

viii. *Curing.*—The concrete must be kept damp for ten days with ordinary, or four days with rapid hardening concrete.

GRAVEL ROADS

8. Gravel occurs in many parts of the world where other type of stone is not available, and has been extensively employed in road construction. The foundation should consist of gravel of any size up to 6-in. diameter and spread some 11 in. in depth and well rolled and watered.

The surface coat consists of about 2½ in. broken gravel, spread to a depth of 3 in., rolled and watered and rolled again until all movement ceases. Traffic is admitted and after about one week a sealing coat of bituminous emulsion at rate of 1 gal. to 2 sq. yds. and hard stone chips is applied and rolled.

The surface may be grouted as explained in Table 13, the surface coat being rolled dry. The gravel in this case must be washed and free from sand.

" MIX IN PLACE " GRAVEL, SAND AND EARTH ROADS

9. Almost any kind of soil or sand except clay can, by treatment with oil or bitumen, be made into a satisfactory temporary surface for rubber-tyred vehicles.

The process consists in first pulverizing the soil with hand tools or with harrows to a depth of 2 to 4 in. The soil is then spread uniformly over the surface.

The binder is then distributed over the surface at the rate of 1 gal. to 2 sq. yds. and thoroughly mixed either with rakes, or with special grading machines. Two or three such applications may be necessary depending on the nature of the soil and the binder used. Each type of soil must be treated on its merits and experiments will be made to determine the most suitable binder and quantity. After it has been thoroughly mixed it is spread to correct shape, lightly rolled and allowed to dry out.

When it has dried out it may be sealed with chippings and bitumen as previously described.

Tractor drawn machinery is now available for the whole process of grading the formation and mixing with the binder, and in favourable circumstances a rate of construction of 4,000 ft. of 10-ft. road a day may be expected.

10. *Plant mix.*—The same type of road may be made by

mixing the earth and binder in an ordinary concrete mixer, when it is known as the *plant mix* method, but progress will be far slower, each mixer being capable of about 150 ft. of road 10 ft. wide a day.

11. *Surface layer method for gravel, sand or earth roads.*—This method consists of spraying a priming of road oil or bitumen at the rate of 1 gal. to 4 or 5 sq. yds. on to the surface which must be in a firm, hard condition.

A second application is then given at the rate of 1 gal. to 3 or 4 sq. yds. and immediately covered with chippings. No rolling is done. This type is of no use where animal traffic is expected. The surface layer will require periodical removal and will become gradually thicker and stronger.

PAVED ROADS

12. For cities, towns and where very heavy traffic is found, paved roads give longer life than macadam. The military engineer is not likely to be called upon to construct such roads, but may have to maintain them. The following are the types most likely to be found :—

i. Stone setts.
ii. Asphalt.
iii. Wood blocks.
iv. Bricks.

For details of constructions, *see* Plate **136.**

Although a concrete foundation is usual in cities, docks, etc., the *pavé* met with in France on the main roads is laid direct on sand with no other foundation than the natural soil. Maintenance is dealt with in Sec. **99.**

ROADS IN MOUNTAINOUS COUNTRY

13. The principles of road construction laid down in the foregoing paragraphs will apply equally to those in mountainous country and they differ only in the greater complication of drainage, steeper gradients, sharper curves, excessive rock cutting and wall building, details of which are given in Military Engineering, Vol. V.

HILL TRACKS

14. Hill tracks may be constructed in mountainous country either for the use of pedestrians, ponies, mules, etc., where wheeled traffic is not suitable, such as the track leading up to a permanent piquet post of a defended camp.

They should take every advantage of the steeper gradients and curves that pack transport can negotiate. Short lengths of 1 in 5 may be permitted but 1 in 10 should be the working gradient. Level stretches of 50 yards in length every mile or so should be arranged for resting animals.

The width should be 10-ft. for double traffic, including 1-ft. drain, and 4 ft. for very difficult country or temporary track provided passing places are made in sight of each other. The road surface is given a slight slope (1 in 10) towards the inner side to an inner gutter. On sharp curves the width should be increased by 4½ ft. for single-line traffic, and 1½ ft. for double-line traffic.

On long steep slopes the surface should be herring-boned by building slight ridges of stone (1½ in. thick and sunk into the road to a depth of not less than 12 in.) or timber across the road at an angle of 45 degrees to the road, projecting slightly above the road surface to force the water into the drain.

A layer of 1½-in. stone 4 in. deep is spread over the formation, large stones being used to form the drain at the inner side. Over this foundation a surface of smaller stones with a little sand or earth to act as binder is spread. Any consolidation required will have to be done with hand rammers.

The surface water will be passed across the road by scuppers or Irish bridges. Culverts will only be necessary over the larger streams and will generally be made of timber.

Retaining walls will be made sparingly and of dry stone work.

For details, *see* Military Engineering, Vol. V.

97. Temporary roads

PLANK OR CORDUROY ROADS

1. These are used for deviations, approaches to temporary bridges, railhead dumps or engineer parks.

Any kind of straight timber of the required thickness will serve for corduroy, but larch, spruce and fir are the best. For convenience in handling they are cut into lengths of 10 ft., so that the overall width of a single or double road is 10 or 20 ft. respectively.

For motor traffic the corduroy should be of average diameter of 6-in. ; slabs or planks should be 3 to 4 in. thick.

For horse transport corduroy can be 4 in. in diameter and slab or planks 2 in. thick. Ribands should be 6 in. by 6 in. in every case.

2. The following is the process of construction for a double-way corduroy or plank road, of which cross sections are shown on Plate **137** :—

i. Peg out centre line.

ii. Mark out side drains leaving berms of at least 4 ft. in width.

iii. Excavate drains and throw earth into the centre of the roadway; ram this, giving an initial camber of 6 in. at the centre line to allow for sinking. The side drains must be deep enough to drain the earth formation.

iv. Bed the transverse bearers or sleepers at 5-ft. centres into and level with the surface of the formation.

v. Lay stringers or runners as shown on Plate **137**; augur and spike to every transverse bearer; spike the two centre stringers together and ram earth between the stringers.

vi. Lay the slabs of corduroy close; if the latter is of split timbers, the flat side must bear on the stringers. Augur and spike to all stringers.

vii. Lay the ribands with a space of 12 in. between each to allow surface water to run off. Ribands should be spiked to the road and to stout pickets driven at 3-ft. intervals along the edge.

viii. Fill in the interstices with sand, gravel or earth.

The following are additional points of importance to be observed:—

ix. In swampy ground a close layer of fascines should be placed under the transverse sleepers to form a more solid formation.

x. In laying a single-way road, passing places not less than 20 yards long and 10 ft. wide must be provided every 400 yards. At all places where lorries, etc., have to unload, turning places must be provided.

xi. Holes for spikes must be bored, otherwise the wood will split; 6-in. spikes should be used whenever available, as wire nails are not of sufficient strength and are found to bend when driven through hard wood. Great care should be taken that no projecting nails, which might injure animals' feet, are left.

xii. Side drains in soft ground may have to be revetted with pickets, brushwood, planking or expanded metal.

xiii. In corduroy roads where the timber is of irregular size, the surface may be improved by the use of an adze.

xiv. Sand or gravel is a necessity, and must always be at hand for sprinkling on plank roads in frosty weather.

xv. The transverse bearers may be omitted when the ground is firm and the traffic of moderate weight.

WHEEL TRACKS

3. *Wheel tracks* consist of a bearing surface of 2½ to 3 ft. wide under each wheel. Drainage should be provided as soon as time and labour permit. Passing places must be provided at intervals and laid like railway switch lines. They are economical in material and rapidly laid, but are only used in emergency.

They may be constructed of:—

i. Macadam.
ii. Concrete.
iii. Planks.
iv. Corduroy.

The methods of construction are as previously described for roads of similar materials.

Plate **138** shows details of plank and corduroy tracks.

DESERT ROADS

4. In desert country the surface will not be all sand, but may have large areas of stony ground interspersed with rocks and boulders.

In preparing the actual road surface where both sand and rocky ground exist, after marking out the centre line, all the stones, rocks, etc., should be cleared off the roadway, and stacked along the edges. This will give a guide to the roadway if sand silts over it.

5. In *hard ground* two longitudinal side drains should be dug and the soil obtained from them used to fill in irregularities over the roadway. The approaches and exits to all nullahs should be ramped down and clearly marked with pickets, piles of stones, etc. A certain amount of grading may be done providing the soil is stony and not sand liable to be blown. Camel convoys should be encouraged to use the roadway, as their feet compress the sandy soil and smooth out the wheel ruts.

6. *Sandy ground.*—The construction and maintenance of a road surface for light mechanical transport over the hard desert soil prevents little difficulty. The trouble lies in the crossing of the soft sandy portions. Various methods have been tried and that of mixing the sand with bitumen or oil as described in Sec. **96,** 9, promises to give best results. If the

bitumen or oil is not available, some of the following temporary expedients may be used.

7. *Wire netting, wire weaving, expanded metal and 8-gauge army track* are all used with success for getting vehicular transport over stretches of sand. Animal transport can only use roadways made from the army track.

8. The *wire netting* used is the ordinary chicken or rabbit wire, issued in rolls 3 ft. wide; the mesh should not be greater than 1 in. in diameter and the gauge should be No. 18. One thickness of wire can be used for light motor traffic but double thickness is recommended for heavy or continuous traffic. Four widths of netting are laid for a single track, with 3-in. overlaps. The rolls are laced together with plain wire as they are laid. Angle iron or wooden anchor pickets are attached with plain wire to the outer widths of the wire netting and are then driven at the bottom of holes about 2 ft. 6 in. deep dug along the sides of the track, at about 6-ft. intervals. The anchorages are then windlassed up and buried to minimize the danger of tripping.

In the maintenance of this type of roadway the anchorage pickets should be kept firm and the anchorage wires windlassed up taut. If ruts form, they should be filled in through the netting. If ruts are left, the netting becomes pulled out of shape and torn by traffic.

9. The *wire weaving* consists of rolls 3 ft. wide 1-in. mesh and 16 S.W.G. *Expanded metal sheets* 8 ft. by 8 ft., 3-in. mesh are suitable. Both kinds are laid as described, for wire netting and give better life but are more costly to purchase than the wire netting. Owing to their greater strength, ruts do not form so easily as with wire netting and the only maintenance is to keep the anchorages taut.

10. In India extensive use has been made of the 8-*gauge army track* which consists of a diamond mesh woven netting 8 gauge, 3-in. mesh, 12-ft. wide in rolls of 25 yards. To make the roadway, lay out the track on the road, drive and bury short angle iron or wooden pickets anchorages, 6 ft. out from the edges of the netting on both sides and at 5 paces interval on the straight. For sharp curves, short lengths of netting must be cut. At the commencement dig a small trench 12 in. deep under the end of the track and lay about 18 in. from the end of the roll in this trench. Fill in with stones and earth. Where one roll is joined to another roll, overlap the two ends 12 in. and fasten with 14 S.W.G. binding wire every 6 in. Each roll must be pulled taut from the far end. Anchor the netting back to the pickets by 3 strands of 14 S.W.G. wire both at right angles to the road and obliquely and windlass up tight. The edges of the track should be clearly marked with stones, etc. Cover the track with 3 in. of shingle or river bed sand.

11. *Other expedients* for temporary roads over sand are *tibben* (chopped straw) and grass. Six inches of tibben mixed with earth well watered and rammed, will carry horse transport and will also serve as a foundation for light metalling if a roller not exceeding 3 tons is used to consolidate it.

Another method is to dig out the soft sand and replace it by a thick layer (at least 6 in.) of long grass placed at right angles to the centre line of the road.

Alternate layers (3 in. thick) of earth and grass, palm branches or bhoosa kept watered if possible may also be used.

Roads in Bush Country

12. In a theatre of operations where the ground is covered with scrub, bush and thick undergrowth, movement off roads and tracks is impossible. For operations in such countries, if light 6-wheeled vehicles are to be used, metalled roads are not essential, provided any soft or marshy patches can be circumvented or rendered sufficiently firm. In untouched country, a wide clearing off the track will enable light mechanical vehicles to progress. After marking out the centre line, gangs of local native labour should cut down all the bush and timber and remove the stumps. Gradients should be eased, bad spots metalled or corduroyed, streams bridged or banks ramped down to fords which should be well marked. If possible, special tracks should be reserved for M.T. and also relief tracks provided for wet weather, so as to avoid cutting up the dry weather track.

Cross Country Tracks

13. *Cross country tracks* are invaluable for the relief of roads in dry weather, and are provided for the use of artillery limbers serving batteries, the conveyance of rations and stores to the troops, as short cuts to and behind the battle zone areas, and to avoid villages and other shelled areas. In siting tracks, concealment from enemy ground and air observation should be aimed at.

14. Having decided on the route of a track, the necessary work should be carried out as follows :—

Mark out the track throughout its length with posts, which should be placed at intervals of 10 to 20 yards along one or both sides of the track. These posts should be painted white, or have a continuous wire stretched between them with pieces of white tape knotted on to it; they should be closer at corners and difficult places. Two-way tracks should never be less than 20-ft. wide for wheeled transport, and 8 to 10 ft. for pack animals.

ii. Clear and roughly level the track throughout its length. All mud should be removed, and the softer parts of the ground attended to. Fascines are most suitable for this purpose; they should be well wired and picketed to solid ground, and covered with 6 in. of earth or gravel.

Corduroy road-mats (Plate **139**) are also useful and may be used for the junctions with main roads and approaches to camps, horse lines, or water points; mats of chestnut paling are another useful expedient for soft places. If the track is likely to be required for some time, some form of wheel tracks (*see* para. 3, above) may be given over the soft portions. Shell-holes must be filled in and well rammed, but water and mud must first be removed. Brick rubble is useful for filling shell-holes.

iii. Surface drainage must be provided, by means of a ditch on each side of the track. These ditches should discharge into depressions, shell-holes or natural drainage ditches.

iv. Old trenches should be filled in rather than bridged. The filling should be well rammed and covered by corduroy or fascines.

v. Streams and natural ditches should be crossed by light timber bridges, or by culverts formed by timber box-drains, corrugated iron pipes or reinforced concrete pipes.

vi. All tracks should be carefully indicated by notice boards at all crossings, road junctions, and other important points. Map references should be freely given. Tracks must be marked at night by placing lamps hidden from the enemy. A useful method is to place the lamp in an empty biscuit tin, one side of which has been replaced with oiled linen on which the necessary directions have been painted in black lettering. Luminous paint is useless for marking tracks as it is invisible except at close quarters.

98. Improving existing roads

1. In *improving existing roads* the first essential is to reconnoitre the road and note any bottle necks or bad corners which will impede the flow of traffic. These should first be treated by rounding off of corners or necessary widening or by small deviations.

In the case of *unmetalled roads* the question of drainage is usually of primary importance. Except in countries with a very dry climate, drainage should be attended to first. The surface can then be improved by one of the methods in Sec. **96,** 8.

2. In improving a *metalled road* in poor condition, the order of urgency of the work is:—

- i. Establish longitudinal side drains, and cut wide gaps through the banks of earth, mud and rubbish which it is safe to assume will be found on the berms along both sides of the road. This will enable the road to be drained. (*See* Plate **140,** Fig. 1.)
- ii. Sweep mud and water off the road into the side drain using brooms; scrapers and shovels should not be used to remove mud and water.
- iii. Throw all solid mud, debris or spoil clear of the drains on the far side.
- iv. Repair the worst ruts by cutting them out square and filling in with metal well rammed.
- v. If sufficient road metal is available, restore shape and camber to the surface, treating half the width of the road at a time, length by length. First scarify the old surface, then spread macadam to the required thickness, using a templet, and roll well in. Then finish off in one of the methods described in Table 13 (p. 227).
- vi. Earth berms at the side should not be interfered with, as their removal will leave no support to the metalled width against spreading.

3. *Sunken roads* are generally developments of old tracks cut through undulating country and are often devoid of any drainage.

If the side banks are not too high, the method shown on Plate **140,** Fig. 2, may be adopted to improve the formation. Side drains are cut in the banks at a suitable distance from the edge of the road, and the surface is connected to these by cross drains cut through the bank at intervals.

If the banks are too steep for this treatment, the drainage may be improved by cutting away at the sides and laying gutters to carry off the surface water, until it can be got clear of the road on lower ground. (*See* Plate **140,** Fig. 3.)

4. *Widening macadam or paved roads.*—The work required to effect this improvement is shown on Plate **140,** Fig. 4. The earth sides must be excavated to a depth sufficient to admit of laying the foundation and macadam surface, at the same time keeping the camber of the central portion so that drainage off the surface is not obstructed. The widening should

be carried out only on one side at a time, over a section of the road. If the old ditch comes under part of the extension of the roadway, it should be cut square and all mud removed, and the whole filled up with large stones.

5. *Dust prevention.*—In countries where macadam roads have not been treated with tar or bituminous products, dust will be a great nuisance and may be a menace to the health and safety of the troops. The only satisfactory remedy is the application of tar or bituminous products to the surface by spraying, as described in Sec. **96.** Waste oil from M.T. depots can be usefully employed for this purpose.

99. Road repair and maintenance

1. The wear of a road surface can be attributed to the combined action of traffic and weather. The main cause of destruction is impact. The slightest irregularity in the surfaces produces impact and this rapidly spreads. Water then collects in such hollows and further impact increases the damage. The chief enemy of the road is, therefore, water, and it is the duty of the man in charge of the road to see that water is given every facility to escape from the road and its vicinity as quickly and easily as possible.

Efficient maintenance requires that the surface should be kept smooth so that impact is reduced to a minimum and water may flow away quickly ; incipient ruts, hollows and depressions, which produce impact and where water may lie, should be repaired at once ; mud and loose stones from water bound surfaces, and refuse should be moved ; gutters and channels should be kept clear ; ditches and culverts should be inspected and cleaned out regularly (in tropical countries before the heavy rains set in) ; berms should be kept trimmed ; catchwater drains and watercourses approaching the road should be kept clean and free from obstructions, and bridges examined at frequent intervals.

2. *Water bound macadam roads.*—The principal duties of each man in charge of a section of road will be to keep the surface free from loose stones and mud, to attend to the drainage and to clear out gullies. An occasional sprinkling of sand over the surface will replace any of the binding material worn or washed away. The more frequently mud and dust are removed, the slower will be the disintegration of the surface. In very dry weather roads made of gravelly or flinty material will tend to work loose and some of the binding material will come to the surface. This should not be removed as it will be forced into the road again as soon as the rain comes. Mud should be in sufficiently fluid state to be capable of easy removal. It must be removed from the vicinity of the road. If piled in heaps along the roadside, it may interfere with the side drains or be washed back on to the roadway.

Patching is necessary to keep the surface in good condition, and should not be delayed until the road has got into a bad state, as it saves time and money to patch at once. Ruts and potholes should be cut out square ; if the foundation has been damaged it must be replaced. The metal is then laid and rammed dry till no further impression can be made on it, water is added and ramming continued until consolidation is complete. Finally a binding of chippings is given and rolled in.

A time will come when it will be necessary to renew the surface coat, and it is not economical to wait until the old surface is completely worn away. To effect a renewal, the old surface should be scarified to a depth of about 2 in. and picked up. The old material is screened through a ¾-in. mesh screen and all that passes is rejected. This probably can be used for footways. The retained old metalling is then re-spread on the foundation and sufficient new metalling is added of correct gauge to make a total thickness of 3 in. after rolling. 60 per cent. of old metalling is often available for re-use. The surface can then be finished off in any of the methods described above in Table 13.

In the renewal of a macadam surface good rolling is just as essential as in making a new road. No unrolled stone should be left on the road at night and care should be taken not to leave a vertical or steep edge to the new coating, but the edge should be thinned out so as to afford an easy passage from the old to the new surface. Notice boards warning traffic that rolling work is in progress, should be placed at reasonable distances from each end of the work.

3. *Tar or bitumen bound roads.*—From the nature of this class of road, dust and mud will be practically non-existent but periodical cleansing of the surface is necessary. These roads should be sprinkled with gravel or granite chippings in frosty weather especially on hills.

The important point in the maintenance of the surface is the prompt attention to incipient ruts and potholes and places where the sealing coat shows signs of wearing through. For the repair of ruts and potholes, cut out the hole square, remove all loose material, and allow it to dry thoroughly. Brush the cavity over with hot tar or bitumen and thoroughly ram new material of 1¼ to ¼-in. gauge into it ; grout with tar or bitumen and finish off not more than ¼ in. above the surrounding surface.

If bituminous emulsion is to be used, thoroughly brush out all dust and dirt, heavily coat the surface of the cavity with emulsion and quickly fill in with stone graded 1 in. downwards; well ram and spray the surface of the patch with more emulsion, cover with chippings and ram or roll again.

Spraying the surface of a road as soon as the old surfacing shows signs of wearing through will increase the life of the road greatly and is generally carried out as a routine measure. Before spraying, all ruts or potholes should be made good as explained above and the whole surface is brushed free from dust or dirt and spray is applied as described in Table 13.

When the surface has to be renewed entirely, it is scarified to a depth of about 2 in. and a new layer of pre-tarred metal or a grouted surface coat is laid on. The procedure is similar to that already described above for a new surface.

4. *Paved roads.*

i. *Stone setts.*—In frosty weather, shingle or chippings should be scattered over the surface, especially on gradients.

If a single sett or batch of setts sink, they can be lifted out and relaid, sand being added underneath to bring them up to required level. If badly worn, they can be turned over or replaced, or the spaces filled with concrete.

ii. *Wood blocks.*—Similar to stone sets.

iii. *Asphalt.*—Cut out and relay potholes or depressions as they form. If asphalt is not available pre-coated macadam made with fine aggregate may be made by hand mixing and used to fill the holes.

iv. *Bricks.*—Special bricks must be used. It is no use using ordinary bricks, however hard they may seem. If not available use concrete made with small aggregate to fill up the hole.

FORWARD ROADS—SHELL-HOLES AND MINE CRATERS

5. The repair of *forward roads* during operations must be carried out rapidly, in order that communication may be interrupted as little as possible. An enemy in retreat will do all the damage he can to the road system in addition to that from shell-fire and use.

The problem before the engineers is to get the traffic forward at the earliest practicable time, using local materials. Temporary detours, bridges, and culverts will have to be constructed and all obstacles removed; some form of wheel track may be the quickest method. The original road is repaired as rapidly as possible, but this is subsidiary to expedients to keep traffic moving. In clearing obstacles, a passage of about

10 ft. should first be provided. In opening up a passage through the ruins of a town, care should be taken that vehicles in passing cannot strike projections. Ruins likely to be shaken down by vibration of traffic should be demolished and removed.

Damage in the form of old trenches, shell-holes or mine craters should be repaired as follows:—

i. *Trenches* cut in the roadway being comparatively narrow may be bridged or filled in. Time may be saved by using sandbags. Surfacing materials may be improvised from fascines, logs, planks or broken bricks.

ii. *Shell-holes* vary in size considerably. They should be cut out square and all mud and water removed. In a small hole, if the original foundation of the road has been destroyed, it must be replaced by large stones and macadam rammed over it. For dealing with larger holes, after cleaning out they must be filled with earth well rammed, sandbags, short fascines or small cribs of pit-props filled with earth or gravel. The foundation and metal are laid on this filling in the usual way. Plate **141** shows different methods of filling shell-holes.

iii. Large *mine craters* may be as much as 100 ft. in width and 50 ft. in depth. When these occur a diversion of plank or corduroy roadway should be given to restore communications. Such diversions are generally made round each side of the crater for up and down traffic; they should be clear of the loose material thrown up by the explosion, which is required for filling purposes.

For filling large craters, parties of men are needed with wheelbarrows, picks and shovels. The following method of filling is recommended (Plate **142**):—

(*a*) Remove all sludge and water.
(*b*) Fill up to within about 2 ft. of the road surface with layers consisting of alternate courses of sandbags filled with dry earth and properly laid, and of dry earth well rammed.
(*c*) One layer of fascines, stretchers, breaking joint.
(*d*) Ram in dry earth to fill spaces.
(*e*) One layer of fascines, headers, breaking joint.
(*f*) A few plank stretchers along the line of traffic.
(*g*) Dry earth rammed to make a flat surface.
(*h*) A corduroy roadway.
(*i*) Road metal to finish off the surface.

CHAPTER XXI

TRAMWAYS

100. General

1. Tramways are not a transportation service. They will often be useful for the following purposes :—

- i. In depots, for reducing manhandling from broad-gauge sidings to the stacking areas and for facilitating internal working.
- ii. For constructional purposes, such as the levelling of sites and carrying out any heavy earthwork.
- iii. In forward areas during protracted operations for distributing ammunition, engineer stores, rations and personnel.

2. They may be operated by manual labour or animals, or by petrol or steam tractors.

3. Even if of the same gauge as the light railways and starting from the light railway termini, tramways will normally be treated as isolated systems and interchange of rolling stock will be inadvisable.

101. Description of track

1. *Gauge.*—Measured between the inside edges of the rails, it may vary from 18 to 30 in., but the most usual is 24 in. equivalent to 60 cm. on the Continent.

2. *Rails.*—Are of flat bottom section and vary in weight from 10 lb. a yard upwards. The most usual sizes are 10 lb. for light push lines and 20 lb. for other purposes (Plates **143** and **144**).

3. *Details of design.*—Sleepers are generally of light pressed steel spaced $39\frac{3}{8}$ in. apart. The rails are fastened to the sleepers by a variety of methods.

Rivets or clutch bolts (Plate **143**) are used for rails up to 20 lb. a yard.

Clips and bolts (Plate **144,** Fig. 1) or clips and wedges (Plate **145,** Fig. 2) are used for any size of rail.

If timber sleepers are used, rails are fastened by dog spikes

Rail joints.—For rails fastened by clutch bolts joints are made by double sleepers ; or other types by flat or angle fish-plates.

4. *Straights and curves.*

- i. Straight lengths are supplied in 15 or 18-ft. lengths as a rule with 5 or 6 sleepers respectively, and in half lengths.
- ii. Standard curves of 13 ft. 3 in., 37 ft. and 65-ft. radius are the types commonly in use. 2, 4 or 8 sections respectively make up a quarter circle or 90 degrees curve. Rails can be bent to any curve required by the use of a rail bender.

5. *Turnouts and turntables.*

- i. *Turnouts.*—These are generally supplied riveted together complete, the length of the curved and straight portions being the same or in multiples of the standard track and of radius corresponding to the standard curves. Plate **145** shows a typical turnout of 65 ft. radius for 20 lb. track.
- ii. *Turntables.*—Where wagons are propelled singly by hand, turntables are useful for quick changes of direction or where a number of short spurs are to join on a single line. There are many different patterns in commercial use. Plate **146** shows a light portable type that can be placed anywhere on top of an existing track.

6. *Trucks and wagons.*—Are available in many forms. The most common type for hand or light tractor propulsion are side tip wagons for earthwork, etc., to carry $\frac{1}{2}$ or 1 cu. yd. and open box wagons of similar capacity. As a general rule the weight of a wagon empty is about one-third of its weight when full of earth.

102. Construction

1. *Location.*—Tramway track is, as a rule, laid on the natural ground, and banks and cuttings avoided by going round the obstacles. A thorough reconnaissance and staking out of the line should always be done well in advance of the earthwork.

The following points should be noted :—

- i. Take fullest advantage of cover from enemy observation even if it involves detour or negotiating difficult features mentioned in ii.

ii. Bogs, marshes, oblique crossings of streams and roads and long cuttings must be avoided.

iii. Avoid localities such as cross roads and prominent objects which attract shell-fire.

iv. All grades should be in favour of the load.

v. Tracks must be sited to suit the standard curves available.

vi. Main lines in forward areas should never go direct to large dumps, batteries or headquarters, but should connect with these delivery points by means of branches or spurs at least 200 yards long.

vii. Lines should never be constructed along the sides of a road surface. It leads to congestion of traffic and damage to the line.

viii. Lines should always be located with a view to drainage of the formation, *i.e.* they should not go up the centre of a valley, but should be constructed a little up the side slopes.

2. *Gradients* should be kept as low as possible where loaded traffic is in one direction only, the line may be located with a steeper gradient against empty traffic than against loaded traffic.

Normally gradients should not exceed 1 in 50 or in extreme cases 1 in 33.

3. *Curvature.*—The radius of curves must not be more than 10–14 times the wheel-base of the wagons used for man or animal haulage and 15–20 times the wheel-base for tractors. Curves increase the resistance to traction. When curves occur on gradients, therefore, the gradient should be slightly reduced. In general, use the easiest of the standard curves available.

4. Passing points should be allowed every ½ mile.

5. *Earthwork.*—

i. In the first instance as little earthwork as possible should be undertaken, the line being laid on the natural ground and opened to traffic as soon as possible.

ii. Drainage is, however, essential. If omitted, even in the first instance, the track will rapidly become unworkable.

Three typical cross-sections are shown on Plate **147** for construction on level ground (Fig. 1), embankments (Fig. 2), and in cuttings (Fig. 3).

iii. In passing over very soft ground the steel sleeper can be supplemented by wood sleepers to which the rails are fastened by dog spikes or rail screws.

iv. In the case of man or animal haulage some form of track for the feet will become necessary. Either trench-boards, fastened as in Plate **148**, or some form of hard ballast will be found suitable in the case of mules. For men a lighter form of grid can be substituted, but it will be also advisable to ballast the berms between the track and the drain to prevent the formation of mud.

v. Road crossings should be constructed with wooden sleepers to enable guard rails and 2 in. longitudinal planks to be spiked to them (Plate **149**).

6. *Labour.*—

i. In laying 10 lb. track in forward areas the parties should be kept as small as possible and "bunching" should be avoided. A typical distribution for a party of 32 men is shown below :—

	N.C.Os.	Men	Tools and Stores	
(*a*) Preparing ground ...	1	11	Shovels	12
			Picks	4
			Billhooks	3*
			Axes, felling ...	2*
			Wirecutters ...	2*
(*b*) Loading and pushing	1	9	Push trollies ...	4
(*c*) Carrying and laying ...	1	9	Spanners	4
			Picks	2
			Hammers, 6-lb. ...	2

* Required in special cases only.

100 to 150 yards an hour can be laid by this party if materials are delivered at the near end of the line. This is for a maximum push of 500 yards. Add 2 men and a trolley for each 200 yards for longer pushes.

ii. A typical distribution for a party of 100 men to lay a 20-lb. track is shown below :—

	N.C.Os. or skilled men	Men	Tools and Stores	
(*a*) Formation party	2 N.C.Os.	60	Picks	20
			Shovels	30
			Wheelbarrows ...	8
(*b*) Laying track ...	2 Platelayers	10	Steel crowbars ...	2
			Spanners	2
			Beater picks ...	4
(*c*) Carrying track sections ...	1 N.C.O.	20	Push trucks ...	5
(*d*) Assembling track	1 Fitter	10	Spanners	8

This party of 100 men should lay 100 yards of 20-lb. track an hour under normal conditions : this does not allow for ballasting.

103. Maintenance and traffic control

1. *Maintenance.*—A tramway track in operation requires frequent inspection ; at least once in every 24 hours, and also after every bombardment.

The points to be looked for in ordinary inspections are :—

i. Bad packing, water lying on track, rails not at correct levels or alignment, sleepers buckling.
ii. Adjustment, cleaning and draining of points and crossings.
iii. Clutch bolts, in the case of 10-lb. track, and fish plates and clip bolts in the case of 20-lb. track, working loose.

Repairs must be made immediately they become necessary. Materials for maintenance and repairs to track should be distributed for use of the maintenance gangs at convenient points for quick access, and should always include a porportion of curves. All salved track material should be collected at the same points and returned on trucks which have conveyed up new material.

The quickest way to repair a line which has been cut by a shell or bomb is to cut out the damaged rail sections complete and replace by new rail. A large shell-hole is best dealt with by diverting the track round it ; a small one, by filling or bridging with timber or steel, as available.

For a tramway in continual use 2–3 men for each mile should be allotted for maintenance.

2. Every precaution must be taken to prevent unauthorized personnel from using the tramway formation as a convenient track. This may be done by :—

i. Providing an alternative track nearby.
ii. Fencing off the formation and providing notice boards.

Neglect of these precautions will soon result in the destruction of the track.

3. *Traffic control.*—In any extensive system a control staff is required to ensure efficient working, with representatives at termini and intermediate stations. Their duties will include :

i. Issue of trucks on indent which should contain number of trucks required, time, place and load to be carried.
ii. Despatch of trucks. On a heavily worked line timetables will have to be worked out.

iii. Control of loading and offloading places to prevent accumulation of stores.

4. Tractive force in pounds that can be exerted by an average man as compared with animals.

Man	30	All capable of double effort for brief periods.
Donkey	100	
Pony	150	
Mule	200	
L.D. horse	250	
H.D. horse	300	

On portable tracks, tractive resistance averages 20–30 lb. a ton on level. To this must be added on gradients $\frac{2240}{N}$ lb. a ton for a gradient of 1 in N.

TABLE 14.—AXLE LOADS AND WEIGHT OF TRACK

Weight of rail lb. a yard (1)	Pressed steel sleepers		Maximum load for each axle (4)	Weight of track complete a mile (5)	Remarks (6)
	Weight * lb. a yd. (2)	Spacing (3)			
			cwt.	tons	
10	7	39⅜	18	22	Hand traction.
12	7	,,	24	25	Hand or animal.
14	7	,,	30	29	
16	7	,,	34	32	Light tractors.
18	11	,,	40	38	
20	11	,,	46	42	Light locomotives.

* The normal length of sleeper for 24-in. gauge track is 1 metre (39⅜ in.).

CHAPTER XXII

RAILWAYS

104. General

1. Railways are of different types according to the work they have to perform and the country they pass through, but certain general characteristics are common to all.

The construction or repair of any type of railway is comparable to that of an ordinary road, in that :—

i. The cross drainage of the country must be provided for by suitable openings, and the drainage of the rail or road surface itself must be ensured.

ii. The steeper the gradient the smaller the useful load which can be hauled and the lower the speed.

A railway is a road with a special surface which is capable of carrying a very heavy load at high speed. Consequently delays or accidents have serious results, and although, in war, rapidity of construction or repair is likely to be an important factor, principles of safety and necessity for accuracy are of primary importance.

105. Construction

1. *Plan.*—The centre line of a railway is set out in a series of straight lines, connected with curves at places where changes of direction are necessary in order to fit the topography of the country.

Curves are referred to either in degrees, or by their radius in feet (R).

The degree of curvature (d) is the number of degrees in the angle subtended at the centre of the circle by a chord of 100-ft. (Plate **150**). The relation between (d) and R is—

$$R = \frac{5730}{d}$$

To find the radius of a circular curve in feet, stretch a string 100 ft. long on the inside edge of the curved rail and measure V, the distance in inches from the middle of the string to the inner edge of the rail.

Then $$R = \frac{15000}{V}$$

To find the degree of curvature stretch a string 62 ft. long in the same manner. The degree of curvature is approximately the same as the number of inches measured from the middle of the string to the inner edge of the rail.

2. *Profile.*—The gradient of a line is expressed either as a percentage or as a fraction, *e.g.* a vertical rise of 2 ft. in 100 ft. horizontally is shown as a 2 per cent. gradient or 1/50.

On railways, as compared with roads, gradients impose much stricter limits to the load that can be hauled. The resistance due to friction on a railway is only 6 or 7 lb. a ton, whereas with road transport it is never less than 20 lb. a ton, rising to as much as 100 lb. a ton on poor roads. A resistance due to gravity of 22·4 lb. a ton has to be overcome in hauling any load up a 1 per cent. gradient on a road or on a railway. It can therefore be seen that the ratio between the tractive effort necessary when climbing and when running on the level is much greater for a locomotive than for a road vehicle The load that can be hauled over any section of railway will be limited by the maximum gradient in that section; for this reason a "ruling gradient" (*i.e.* a gradient which must not be exceeded) is decided on for each section of the line.

Curves also add to the resistance, and an allowance for this is made by the railway engineers when considering the maximum gradients on a line.

When a temporary low level deviation is made, *e.g.* to replace a demolished bridge, the gradients may exceed the maximum gradients on the line in order to avoid an impracticable amount of earthwork; the climb up from such a deviation is accomplished by splitting the train.

It is not advisable to exceed a grade of 4 per cent. (1 in 25) in any circumstances.

3. *Superelevation.*—In order to improve running conditions the track is usually canted on curves by raising the outer rail relatively to the inner rail. For slow speeds this is unnecessary.

Curves will not be given any superelevation unless orders are given to do so by an officer.

4. *Widening of gauge on curves.*—Gauge should be widened on curves sharper than 5 degrees to reduce resistance and wear of rails and tyres. With 4 ft. 8½ in. gauge ¼ in. of slack should be given for curves from 5 to 10 degrees and ½ in. for curves between 10 and 15 degrees.

5. *Formation.*—Plate **151** shows a cross-section of a typical railway formation.

Good drainage is always most important. Adequate side drains are therefore essential, and, if necessary, catch-water drains. Drains and culverts must be kept clear of obstructions and debris.

For temporary tracks and where for any reason ballast is not available the sleepers may rest direct on the earth formation, but when this is done the earth surface should be shaped as far as possible to prevent water lying round the sleepers. Normally, however, some form of ballast is used in order to drain the underside of the sleepers, to hold the track in position and to distribute the load evenly on the surface of the formation; sand, broken stone, broken brick, gravel and ashes can all be used as ballast.

6. *Permanent way.*—

i. *Rails and components.*—Rails are laid to gauge; *i.e.* at a certain distance apart inside to the inside of the heads of the rails, their ends are fastened together with fish plates and bolts, and they rest either in chairs, on bearing plates, or directly on sleepers to which they are usually fixed by spikes or coach screws. Rails may be laid with the joints square, *i.e.* with the joints on one side of the track opposite the joints on the other side of the track, or staggered, *i.e.* with the joints on one side of the track approximately opposite the centres of the rails on the other side of the track. Normally, joints are staggered on curves.

ii. *Sleepers.*—Sleepers may be of wood, iron, steel, or concrete. For military railways, fourteen sleepers to a 36-ft. rail is standard.

iii. *Expansion.*—When two rails are fished together a small space is left between them to allow for expansion due to changes of temperature. The amount to be left depends on the temperature of the rails at the time of laying and will normally be decided by an officer. A flat piece of steel is inserted in the joint whilst the rails are being fished up and is removed when the fish nuts have been tightened.

7. *Turnouts* (*on points and crossings*).—The object of turnouts is to pass trains from one line to another. The lay-out of a turnout and the nomenclature of its parts are shown in Plate **150.** The laying or relaying of turnouts will not normally be undertaken without plans showing the dimensions of the turnout in detail and the spacing of the sleepers.

Points are known by the length of the switch blades in feet and by the switch number, K.

$K = \frac{S}{C}$ where S = the length of the switch blade in inches and C = the clearance between running edges of the rails in inches at the heel of the switch (*see* Plate **150**).

The crossing or frog is built up in one piece and is known by its "number," N. To find the number of a crossing measure the number of feet between the two places one on each side of the nose where the running edges of the rails are 6 in. apart (*see* Plate **150**).

8. *Level crossings.*—Level crossings should be made at all places where road vehicles cross railway tracks.

Plate **152** shows an improvised level crossing.

9. *Platforms and end loading ramps.*—Typical designs of platforms and end loading ramps are shown in Plates **153** and **154.** The distance of the face of the platform from the track, the height of the platform above rail-level and other details may vary on different lines and will be supplied by an officer.

10. *Water supply.*—An adequate supply of water is essential. It should be possible at a watering point to fill a locomotive tender holding from 3,000 to 5,000 gallons in 5 to 10 minutes.

Storage capacity is necessary according to the number of trains to be dealt with and the rate of yield from the water supply.

A temporary water station will normally include a raised storage tank connected by 6-in. piping to an improvised water column. Frost precautions should be taken when necessary. At water stations an inspection pit between the rails about 3 ft. deep and at least 12 ft. long should be made.

Water containing a large amount of silt should stand twenty-four hours in settling tanks before being pumped to the raised tanks.

106. Maintenance and repair

1. *Maintenance of the track.*—

i. *Alignment.*—The correct alignment may be shown by centre line pegs; if there are no pegs the N.C.O. in charge of the maintenance party must judge the alignment by eye, by sighting along the rails. To slew the track, he should stand at some distance from the party and direct where and how much the track must be moved across by crowbars.

ii. *Level.*—The correct level of the rails may be shown by level pegs; without them the lifting of depressions is all that can be done. It is important that depressions at rail joints should be corrected, particularly on curves. The track is raised by means of track jacks and ballast is rammed under the raised sleepers for a width of 16 in. on each side of the rail seat. The jacks are then removed. Lifts should not exceed 3 in. at a time.

iii. *Inspection.*—The N.C.O. in charge of the maintenance party is responsible for the continuous inspection of the track in his section. His duties include noting and remedying all faults in alignment and level, checking cant and gauge, packing low joints and loose sleepers, replacing defective material, keeping clean the working parts of switches, keeping fastenings tight, examining all bridges, and clearing blocked culverts.

2. *Hasty repairs to damaged railways.*—

i. *Permanent way.*—Repairs that can be carried without trained platelayers will be limited to the replacement of rails and sleepers. The following points should be noted.

(*a*) The undermentioned tools are desirable for a party of twelve men :—

Twelve wood beaters ; 6 square-nosed and 3 R.E. shovels ; 6 baskets or wheelbarrows ; 3 augers ; 1 adze ; 1 sledge ; 1 hand and 2 spiking hammers ; 1 jim-crow ; 4 claw bars ; 4 pinch bars ; 1 adjustable and 3 fish-bolt spanners ; 1 ratchet brace with drilling clamp and 6 drills ; 1 rail saw ; 1 oil can ; 1 centre punch ; 1 cold chisel ; 1 T square ; 1 straightedge ; 1 100-ft. tape ; 1 2-ft. rule ; 4 track jacks ; 1 track gauge ; 1 spirit level ; 1 material trolley ; fog signals ; red and green flags and lamps.

(*b*) The rails must be laid tight up to the piece of steel which is used to measure the expansion space (*see* para. 6, iii, above).

(*c*) Correct gauge must be maintained. One rail should be spiked first and then the second rail spiked to gauge. Spikes must be driven vertically and square to the rail ; while the spike is being driven the sleeper must be held up tight against the rail by one or two men with crowbars. The gauge must be checked at each joint and at the middle of each rail.

(*d*) Rails may be cut by special railsaws, or by nicking round the rail with a cold set and then straining the nick with a rail-bender (" jim-crow ").

(*e*) Joints must be bolted up as tight as one man can tighten them with one hand using a standard fish-bolt spanner. For temporary repairs, provided speed is restricted, two bolts only need be used at first on straight track ; on curved track four bolts are always required.

(*f*) When a portion of track is renewed with rails of a different pattern, special fishplates must be made to fit the different types of rail on either side of the joint.

(*g*) Before a train can pass over a length of new or repaired track at anything over a walking speed, the line must be aligned and the sleepers well packed (*see* para. 1, above).

(*h*) On the straight, rails must be at the same level. On curves they should also be on the same level unless superelevation has been ordered by an officer (*see* para. 3, above).

ii. *Bridges.*—Rails may be used as girders up to 12-ft. span. The following rough rule may be used, provided that the rails used are of approximately the same weight a yard as those in the track :—

For spans up to 6 ft. use three rails as a girder under each of the two running rails. For spans over 6 ft. and up to 12 ft. use one rail for each 1½ ft. of span under each of the two running rails, *e.g.* a 10-ft. span needs seven rails under each running rail. Every other rail should be turned upside down and the rails should be wired or clamped together.

Damaged piers and abutments must be replaced. Sleeper cribs or heavy timber trestles are suitable.

iii. *Locomotives and rolling stock.*—Repairs to locomotives or rolling stock will not normally be carried out without the assistance of trained personnel.

PART V—DEMOLITIONS

CHAPTER XXIII

EXPLOSIVES AND DEMOLITIONS

107. General

1. *General principles.*—For the tactical principles of demolitions, *see* Field Service Regulations, Vol. II, and Engineer Training.

2. *Uses of demolitions.*—

i. The main uses of demolitions in warfare are :—

(*a*) To delay the advance of an enemy by the destruction of communications over which he must pass, or of accommodation that he might occupy, or of material that would fall into his hands (defensive).

(*b*) Impairing an enemy resistance by the destruction of captured communications that cannot be permanently held, or of materials that cannot be removed, as, for instance, in a raid (offensive).

(*c*) Destruction of obstacles to facilitate the advance of our own troops (offensive).

ii. *Objectives for demolition* thus fall into three classes—communications, obstacles, and material. In the last two cases the objective is clearly defined. Notes on methods of destruction are given in Sec. **117.**

As regards communications, the guiding principle is to make a complete break in all communications crossing a given stretch of front. As time permits this line should be thickened by further demolitions into a zone or zones of destruction. Points on communications should be selected where no alternative route exists or can be quickly provided. The junction of two or more communications is a very suitable point of attack.

To carry out the above principle demands a clearly defined plan conforming with the requirements of the General Staff, and thoroughly detailed reconnaissance is essential.

3. *Types of demolition.*—There are two main classes of demolitions, hasty and deliberate.

i. *Hasty demolitions* are those when there is likely to be insufficient time to prepare the complete demolition without interruption from the enemy. The quickest and simplest methods must be used, and charges increased to allow for errors in calculations, hasty fixing, improper contact, etc.

ii. *Deliberate demolitions* are those when there is sufficient time for reconnaissance and proper preparation and placing of the charge or charges, though time may not admit of the most efficient or economical method being used.

Points to be considered are :—

(*a*) the time at which the enemy is expected to arrive, and

(*b*) the earliest time at which he might arrive.

First a preliminary demolition is prepared that will ensure a demolition in case of a break-through. Then further demolitions are prepared to ensure complete destruction and a more effective obstacle. If possible, the preliminary demolition should form part of the scheme for the complete demolition, but a demolition ready for firing must always be in place. It may be necessary to prepare the preliminary demolition under hasty conditions.

iii. *Demolition of communications.*—Considerable damage can be done to communications without the aid of explosives. Methods of carrying out such demolitions are included in Sec. **117.**

4. *Responsibility for giving the order to fire a demolition.* (*See* Field Service Regulations, Vol. II, and Engineer Training.)—The engineer officer or N.C.O. in charge of the demolition will be given in writing :—

i. The title of the officer who will order the firing.

ii. Instructions that he is to fire the demolition when the enemy reach a certain position.

He will report to the headquarters concerned the time of the demolition when carried out and the extent of the damage effected.

108. Explosives

1. *General.*

i. *Low and high explosives.*—Explosives are of two classes, low explosives, which function by explosion, and high explosives which function by detonation.

ii. *Explosion* is a rapid form of combustion, usually started by ignition, producing a more or less steady pressure or lifting effect. Low explosives are used in warfare as propellants.

iii. *Detonation* is a sudden change from a solid to a gaseous state, taking place almost instantaneously throughout the whole bulk of the explosive. Even so, a very slight difference in the rate of detonation is sufficient to determine whether a high explosive is suitable for local shattering action (high rate of detonation) or for lifting purposes (low rate of detonation). High explosives are suitable for demolition purposes and are used for this work in modern warfare. The more sensitive high explosives can be detonated either by ignition or percussion, but the stabler forms and, therefore, those which can be used in bulk and handled with safety, can only be detonated satisfactorily by severe shock, their tendency when ignited being not to detonate immediately but to burn until a sufficiently high temperature has been generated to detonate the mass.

2. *Explosives available in the field.*

The following explosives are typical of those which will normally be available for use on service :—

i. *Guncotton.*—For cutting and shattering effect. Carried by field companies..
ii. *Ammonal.*—For lifting effect as in mined charges.
iii. *Dynamite.*—Where a plastic shattering explosive is required, as in blasting rock.
iv. *Amatol.*—Similar to ammonal, but less powerful.

These last two are obtained from civilian stocks.

3. *Wet guncotton* is compressed nitro-cellulose, damped with 15 to 20 per cent. of water. The addition of the water renders it safer to store and handle, and increases its effect on detonation. It is issued in 1 lb. slabs, 6 by 3 by 1½ in. in size, provided with a tapered 1¼-in. hole for the reception of a guncotton primer. It is packed in sealed tin cases containing fourteen slabs each.

Guncotton is a powerful and rapid explosive producing great shattering effect while, owing to the form in which it is provided, it is easily and quickly fixed in contact with the object to be destroyed. It is suitable for demolitions requiring comparatively small quantities of explosives in which close contact with the object to be destroyed is essential as, for instance, the destruction of rails and girders. It is unsuitable for large mined charges, as complete detonation of such charges is not always certain, and its action is too rapid to produce a good lifting effect.

Dry guncotton is compressed nitro-cellulose without any additional water. It is very inflammable, burning with a fierce hot flame. If exposed to the sun's rays for a long period it may detonate spontaneously. It must never be cut, as the friction is liable to cause ignition.

4. *Ammonal* is a grey or sandy composite powder. It is issued in damp-proof tins containing 25 lb. and 50 lb. in which it should be kept. In peace it is packed in 100-lb. cases, for issues of 50 lb. and over, and in 2½-lb. cartridge cases for smaller amounts. It deteriorates rapidly with exposure as it absorbs moisture readily.

Ammonal is slower in action than guncotton and hence more suitable for mined charges, producing a better lifting effect. When used for small charges requiring accurate fixing and close contact it must be placed in a special container. Its shattering effect, too, is less than guncotton, and for these reasons it is not so well adapted for cutting charges, but is useful in boreholes.

Ammonal is liable to solidify in large lumps after long storage, and in this condition its sensitiveness is reduced. Such lumps should be broken up before the explosive is used.

5. *Dynamite* is a plastic explosive, used extensively commercially. It is manufactured in several forms, gelignite, gelatine dynamite, blasting gelatine, etc. It is usually issued in 2-oz. cartridges wrapped in parchment paper and packed in boxes weighing 5 lb. and 50 lb. It cannot be used when wet, as it becomes dangerous to handle. It freezes at 40° F., and remains frozen at higher temperatures, and will then not detonate completely. Frozen dynamite is harder, more brittle and of a slightly lighter colour than when unfrozen.

Thawing dynamite is a dangerous operation. It may be thawed by placing it in an empty watertight tin can, placed in a vessel of hot water (heated separately to a temperature that can be borne by the naked wrist, *i.e.*, about 130° F.) or else in a proper warming pan (Plate **155**). Dynamite should never be warmed on or before stoves or fireplaces, nor exposed to the direct rays of a tropical sun. Dynamite may be thawed in an emergency by putting it in a pocket next the body.

Dynamite is poisonous, and causes headache by mere contact with the skin. Handling with bare hands should therefore be avoided unless the explosive is still in its parchment covering.

"Arctic," "Polar," gelignites freeze at lower temperatures than ordinary nitroglycerine explosives, and so can be used with more freedom in cold climates.

Dynamite and its modifications are the most powerful explosives in practical use. Their action is even more local and shattering than guncotton. They are not so safe to store and handle as wet guncotton or ammonal, and therefore are not carried by units in the field but, being plastic and of such power, they are very suitable for use in small boreholes and narrow irregular spaces where it would be difficult to fit a charge of guncotton.

6. *Other explosives.*—

i. *Gunpowder* (black). Gunpowder is a low explosive, and will not detonate. It is stable when dry, but is completely spoilt by moisture. It ignites readily, and burns with certainty and great regularity. Its main use in demolitions is in the core of safety fuze.

It has no shattering effect, but can be used for mined charges when no other suitable explosive is available, or in small charges when certainty of action is more important than power. It has about one-third the power of ammonal. As the smallest spark will ignite gunpowder, steel tools should never be used close to a charge. Great care must be taken when firing with safety fuze that sparks from the fuze cannot prematurely ignite the charge, which should be in a container to protect the gunpowder.

ii. Numerous other high explosives used commercially may become available on service. Reference should be made to Military Engineering, Vol. IV, 1934, Sec. 5, Table A.

NOTE.—*Plastic high explosive.*—Experiments are being carried out with a form of plastic high explosive. The increasing use of power tools and borehole charges requires that a suitable explosive of this type should be available in the field.

Though primarily intended for borehole work it is probable that a form of plastic high explosive will replace a portion of the guncotton now carried in field units as it will also be suitable for mined and cutting charges.

The technique for use and the necessary formulæ will be published in due course as addenda to Military Engineering, Vol. IV.

The main properties of the plastic high explosive will be as follows :—

Velocity of detonation. 7,000 m/sec. (approx.).
Relative expansion in lead block. 110.
Not liable to freeze.
Not affected by damp.
Will normally form CO.
Not poisonous to handle.
Not sensitive to shock.
Detonated by a special detonator or direct by F.I.D. Mark III.

109. Primers, detonators and fuzes

1. Most high explosives cannot be directly detonated by ignition and in the case of wet guncotton the following auxiliary explosives are needed to commence the detonation :—

i. Primers.
ii. Detonators.
iii. Fuzes.

The fuze when lit ignites the detonator that detonates the primer which, in turn, detonates the wet guncotton.

The few grains of fulminate composition contained in the detonator are not sufficient to detonate unaided the wet guncotton and certain other stable explosives. The detonating shock set up by the detonator, therefore, has to be amplified by a primer of explosive more sensitive than wet guncotton, which acts as a medium of detonation between the detonator and the bulk explosive.

2. *The service primer.*—The service primer is made of dry guncotton. These primers are issued in the form of a tapered cylinder with a hole in the centre for the reception of the detonator. They are chemically coated to keep them dry, and are packed in sealed tin cylinders containing ten primers. They are shaped to fit closely the hole provided in the wet guncotton slab.

3. *Service detonators.*—Two forms of detonator are used for explosives on service.

i. *The No. 8 detonator* for use with safety fuze or F.I.D. It consists of a copper tube 2¼ in. long and $\frac{7}{32}$-in. in diameter. The lower end is closed and 1¼ in. of this tube are filled with fulminate of mercury composition ; the rest of the tube is left open to receive the fuze. The fuze placed in the open end of the tube burns down to the fulminate, ignites it and causes it to detonate. No. 8 detonators are painted red and are packed in red tin cylinders containing twenty-five. A new pattern of detonator may be met that has an aluminium tube, is slightly larger in diameter and in which azide-styphanate-tetryl forms the detonating composition.

ii. *The No. 9 electric detonator, Mark IV.*—The detonating material—thirty grains of fulminate of mercury—is enclosed in a tinned plate tube, closed at the lower end with shellac putty and secured at the top end to a brass socket, which encloses a brass cup containing a priming composition of gunpowder dust and mealed powder. Embedded in the priming is a silver platinum bridge, ·25 in. long, the ends of which are connected to two copper poles which are soldered to the electric leads. The top of the detonator is enclosed by an ebonite head through which pass the leads from the poles. The head fits over the brass socket. Above the head the leads are insulated and bound together with waxed black thread.

The head of the detonator and socket are painted yellow and the tube red. The detonators are packed in yellow and red-tinned plate cylinders (twenty-five in a tin).

The total resistance of the detonator is 2·6 ohms. at fuzing point. When a current of not less than 0·86 ampere is passed through it, the bridge becomes white hot and fires the priming which detonates the fulminate.

iii. *The No.* 13 *electric detonator, Mark III*, consists of a copper tube containing fulminate of mercury similar to the No. 8 detonator, but enlarged at its upper end to receive an ebonite plug. Two short copper leads, insulated with a rubber covering outside the detonator, are passed through this plug ½ in. part. The ends of the leads inside the detonator are connected together with a piece of fine iridio-platinum wire just above the fulminate of mercury. On a current of sufficient strength (not less than 0·8 ampere) being passed through the copper leads, the fine wire is raised to a white heat and fuzes, thus igniting the fulminate of mercury and causing it to detonate. The head of the detonator is painted white, and the tube containing the fulminate of mercury, red. The detonators are packed in white and red tin cylinders (twenty-five detonators in each with a rectifier). The electrical resistance of a No. 13 detonator at fuzing point is 2·6 ohms.

iv. *The No.* 14 *electric fuze, Mark IV*, is similar to the No. 13 detonator, but contains mealed powder instead of fulminate of mercury. It can only be used for igniting gunpowder, and is useless for detonating charges of high explosives. The fuze is painted white.

Detonators should be stored separately from other explosives, handled with great care and never left lying about. Never tamper with the fulminate of mercury.

4. *Commerical detonators.*—These are similar to the No. 8 detonator. A No. 6 commercial detonator will fit a service primer and is powerful enough to fire it, but the No. 8 commercial detonator, which is more likely to be met with will necessitate careful rectification of the hole in the primer as it is slightly larger.

Service and commerial electric detonators should never be included in the same circuit when fired in series.

5. *Safety fuze.*—The service safety fuze No. 11 consists of a core of fine gunpowder enclosed in a tube of braided flax, and is packed in hermetically sealed tins containing 48 ft. The end is often sealed with glue and if this is not done the fuze is liable to deteriorate through exposure. Six inches should be cut off before using. It burns at the rate of about 2 ft. a minute, but as this rate is liable to vary it should be checked before use by burning a measured length and timing it. Safety fuze will burn under water. The fuze, placed in the open end of the detonator, burns down to the fulminate contained in the tube, ignites it and causes it to detonate.

Joints between two pieces of safety fuze should be avoided whenever possible ; no joint is ever permissible in a length that has to remain a long time in position. If a joint is unavoidable, cut a semicircular nick taking care to expose the core of gunpowder in each fuze about 1 in. from the end. Then superimpose the two nicked pieces and bind together with a few diagonal turns of strings. To avoid damp, the join should be bound with a few layers of rubber tape and solution.

Safety fuze may be lit by :—

i. Matches. Cut the fuze on the slant, hold the match head against the powder in the fuze, and strike the box on it.

ii. Service pattern igniters. They easily get damp and are not very reliable. Cut the fuze straight across and fit the igniter over it, crimping the tube to fix it firmly to the fuze.

iii. A port-fire. Useful for lighting several fuzes in quick succession. It is an article of store, and consists of a stick of slow burning composition with a wooden handle. Light with a match and put out by knocking against the heel of the boot. Rate of burning : 1 in. a minute.

7. *Fuze, instantaneous, detonating* (known as F.I.D.), consists of a lead tube filled with Trotyl. The fuze must be detonated. It will not detonate if ignited. Its action is practically instantaneous. The stardard service fuze is the Ordnance Factory F.I.D. Trotyl Mark III, which has now replaced the Bickford F.I.D. Trotyl Mark I, as it is more suited to service requirements.

It is quite safe to handle with ordinary care, but it may be detonated with a severe blow. It can be used for demolitions under water, the metal covering rendering it waterproof.

The principal uses of F.I.D. are :—

i. To fire a number of charges simultaneously when firing by fuze.

ii. In conjunction with electric firing to avoid complicated connections and circuits.

iii. To avoid the use of excessive lengths of safety fuze, that would otherwise be required in certain demolitions, such as mined charges when firing by this method.

F.I.D. is issued wound on drums each holding 400 ft. It will usually be found to have several pieces joined by special connectors. These connections should not be relied upon and should be replaced by properly made joints.

The explosive in the fuze deteriorates on exposure to air. About 6 in. of open end should be cut off before using. If the ends of the fuze are liable to be left in a charge for a long time they should be protected. A good method of protection is to cap them with a No. 8 detonator.

F.I.D. will not detonate round sharp bends, which must therefore be avoided. Kinks in the fuze also cause failure by breaking the continuity of the explosive.

110. Firing charges

1. *Alternative methods.*—

i. All explosives may be fired :—

(*a*) Electrically.
(*b*) By safety fuze alone.
(*c*) By F.I.D. and safety fuze.

ii. The safety fuze method is simple, and once the charge is laid only a box of matches is needed to fire it, but where several charges have to be fired simultaneously, it must be used in conjunction with F.I.D. This makes the firing circuit more difficult to construct, and also renders it more liable to damage from shell-fire.

iii. The electrical method enables the charge to be fired at a distance and at the precise instant desired, and enables several charges to be fired simultaneously. The electrical circuit, too, can be easily tested. On the other hand electric leads are very liable to damage by shell fire, and for safety require burying 7 ft. deep ; 2 ft. gives protection from bullets and splinters. Where burying is not possible, every use must be made of natural cover (*e.g.* close under parapet walls) for their protection.

Electric firing if carefully installed is very suitable for deliberate demolitions if the leads are reasonably safe from damage. In hasty demolitions the safety fuze method, owing to its simplicity, is usually the more suitable.

iv. All important charges should be provided with at least two means of ignition : in many cases it is a good plan to use both methods.

2. *Firing charges electrically.*—

i. Charges are fired electrically by means of electric detonators connected up in series by insulated cable through which an electric current is passed, the usual source of energy being the service exploder. In the absence of an exploder suitably connected charges may be fired by batteries of Leclanché cells or accumulators or by E.L. mains. (*See* Military Engineering, Vol. IV.)

For firing charges electrically, the stores required are :—

(*a*) No. 9 or No. 13 Mark IV detonators.
(*b*) Electric leads.
(*c*) Dynamo exploder.
(*d*) Box testing and jointing.

ii. *Insulated cables.*—Any insulated cable of suitable electrical resistance may be used. The cable specially designed for demolition in the field and normally available on service is the cable, electric, E.1, Mark II. It consists of six copper and one steel strand covered with vulcanized indiarubber and coated with compound. It is issued wound on wooden drums. The electrical resistance of the E.1, Mark II, cable is 1·31 ohms per 100 yards.

iii. *The exploder, dynamo, Mark V*, is contained in a wooden box, 13 by 8 by 6 in., painted white and fitted with a lid that can be locked. It consists of a dynamo operated by a handle. Its weight is about 25 lb.

To use the exploder pull the handle up as far as it will go, connect the leads of the circuit to the exploder terminals, and force the handle down as swiftly and smoothly as possible. The downstroke of the handle turns the dynamo, and thus generates a current which is at its maximum at the bottom of the stroke, when the handle closes a switch, allowing the current to flow through the leads.

A Mark V exploder will theoretically fire No. 9 or No. 13 detonators in a circuit the total resistance of which (including that of the detonators) is 100 ohms. When an exploder has not been tested to ascertain the actual resistance through which it will fire, it should not be relied upon to fire through more than 80 ohms.

iv. *The exploder, dynamo, Mark VI,* is on a somewhat different principle from the Mark V, weighs 3½ lb., and will only fire through a total resistance of 40 ohms. If untested it should not be relied on to fire through more than 30 ohms. The handle, which is detachable, is turned instead of being pressed down.

Detailed tests for exploders are given in Military Engineering, Vol. IV.

v. To find the appropriate resistance of the circuit add the total cable resistance to the total resistance of the detonators at fuzing point (2·6 ohms for each detonation). If this resistance is beyond the power of the exploder, reduce it by using fewer detonators, duplicating cables, using cables of lower resistance or by firing the main charges only electrically and the remaining charges by leads of F.I.D. from the main charges.

To ascertain roughly if an exploder is in working order connect a No. 9 detonator to the terminals and fire it. Place the detonator in an iron box or under a sod so that it may do no harm when fired.

vi. *The box, testing and jointing,* is a tin box in a leather cover which holds all materials, instruments and tools for testing and jointing electric firing circuits. It is carried by all engineer field units.

It contains :—

For testing :—

1 box of resistance coils (100 ohms).
1 "Q" and "I" detector.
1 box, safety test, cell S.
2 reels (metal) of iridio-platinum wire.
1 chamois leather.
1 box of plate powder.

For jointing :—

1 pair 5 in. side-cutting pliers.
2 tubes of india-rubber solution.
4 cylinders of india-rubber tape.
½ lb. of cotton waste.

vii. *Jointing insulated cables.*—Great care must be taken over the jointing of cables. It should be carried out as follows : Strip off 2 in. of the insulation of each cable, open out the stranded wires and clean each thoroughly with the back of a knife, taking great care not to nick the wires. Cross the ends of the cables thus cleaned at right angles and bend

them round each other making three or four complete turns with each end (*see* Plate **156**). Cut off the spare ends and pinch them in with pliers. Now cut off about 6 in. of india-rubber tape and warm it by rubbing it between the hands. Then bind the tape round the joint (Plate **156,** Fig. 4). Stretch the tape as it is applied. When the joint has been covered with one layer smear the rubber with rubber solution, and wrap the tape on in successive layers until used up, smearing each layer with rubber solution. Do not allow any solution to reach the bare wires of the cable.

Deal with defects in the insulation of the cable in a similar way.

viii. *Testing circuits.*—The following simple tests should be known to all N.C.Os. and sappers. More detailed tests that may sometimes be required, are given in Military Engineering, Vol. IV.

(*a*) *Testing an exploder.*—The fusion test provides a means of measuring the power of an exploder. It consists in finding the maximum resistance through which the exploder will fuze with certainty the bridge of a detonator or fuze. A short length of the iridio-platinum wire is placed between the clips provided for the purpose on the box of resistance coils. The bridge thus formed will be fused by the passage of any current that would fuze the bridge of a service detonator or fuze. The connections for the test are shown in Plate **157**, Fig. 1. The firing apparatus should first be tested through a considerably larger resistance than it is expected to be able to overcome. The resistance is next decreased by steps of, say, 10 ohms until the bridge fuzes, and then increased by smaller steps until the bridge (continually replaced) cannot be made to fuze. The maximum resistance through which the firing apparatus will fuze the bridge of a detonator or fuze is thus ascertained.

(*b*) *The continuity test* must always be carried out after fixing an electrical circuit and before firing. If it is to remain in position any length of time before firing frequent tests should be made at regular intervals with the same test cell and detector. It provides a means of ascertaining that no break exists in a detonator, length of cable, or completed firing circuit. It consists in sending through the conductor to be tested a current not large enough to fire a detonator, but sufficient to deflect the needle of a detector placed in the circuit. The test cell and "Q and I" detector are connected up in series to the conductor to be tested (Plate **157**, Fig. 2). In testing detonators and firing circuits containing them, the " I " coil should invariably be used. On the circuit being closed, the detector should give a deflection, thus showing that the circuit is complete. By this test the continuity of a detonator, series of detonators, lengths of cable, or a completed firing circuit may be verified, but it should be noted that only a complete disconnection or break will be detected. A deflection will still be given by the detector when a short circuit, partial break, or bad joint exists but, if the same cell and detector are used, a difference in the reading will indicate trouble.

(*c*) *The pricker test* (Plate **157, Fig.** 3).—When the existence of a break has been revealed by the continuity test and it is not possible to find it by inspection, it can be located by the use of " prickers," *i.e.* sharp metal pins or awls which can be pushed through the insulation of the cable to make contact with the metal core. The steel-wire core of cable, electric, E.1, can be used to make a pricker. Instruments making large holes are undesirable, in view of the possibility of causing leaks. The test cell may be connected to the cables at one end (the other ends being disconnected if possible) and the prickers, connected by short leads to the detector, pushed one into each cable at suitable points, working from one end. The fault will be found between the last position of a pricker that gives a deflection and the first that will not. Alternatively the test cell and detector may be placed in series between the prickers and the latter worked along one cable at a time, when the absence of a deflection will indicate the position of the fault; this method is preferable when it is not possible to disconnect the the " other " end of the cables, as it does not run the cell down.

In all important work test the detonators and cables for continuity before connecting up as well as the whole circuit when laid.

Detailed tests for electric firing circuits are given in Military Engineering, Vol. IV.

ix. *Summary. The following are the steps to be taken :—*

(*a*) Test the cables for continuity, and lay out from the charge to the selected firing point. If the continuity test fails examine the cable for an obvious break or damaged insulation. If this fails to disclose the trouble carry out a pricker test. Place the ends of the cables at the firing point in the charge of a N.C.O. and keep the exploder box locked, retaining the key, or keeping the handle in the case of the Mark VI exploder.

(*b*) Connect the cable ends at the charge to the detonator leads.

(*c*) Carefully place the detonator, previously tested for continuity, in the charge.

(*d*) Test the whole circuit for continuity.

(*e*) Unlock the exploder box, raise the handle when using the Mark V exploder, and connect the cable ends to the exploder terminals.

(*f*) Push the handle down or turn it swiftly and smoothly to fire the charge.

Where several charges are to be fired simultaneously the procedure is similar. The detonators are connected up in series by lengths of cable as required.

Diagrams of circuits for testing and firing are shown in Plate **156,** Figs. 5 and 6.

3. *Firing charges by fuze.*—In firing charges by fuze the stores required are :—

i. No. 8 detonators or commercial caps.
ii. Guncotton primers.
iii. Safety fuze.
iv. F.I.D. (for mined charges or whenever there is more than one detonator to be fired).

Cut the safety fuze to the length required to give time to get away to a place of safety after it has been lighted. Cut the end to be inserted in the detonator straight across; cut the other end on the slant to expose a larger surface for lighting.

Measure the length of the open tube of the detonator by poking into it a thin match or piece of stick or grass, and insert a corresponding length of the straight cut end of the fuze. Put the fuze home gently. Never use force or twist the fuze. Hold the detonator at the open end, with the closed end pointing away from the body. Gently pinch the open end of the detonator on to the fuze with a pair of pliers, or between the marlin-spike and handle of a G.S. knife, to make it grip and prevent it being withdrawn. Take great care that no pressure is put on the closed end containing the fulminate

Test the primer to receive the detonator. If the hole in the primer is not large enough, enlarge it by means of a "rectifier" (a wooden tool made for the purpose) or any other suitable piece of hard wood; if the hole is too large, wrap paper round the detonator to make it fit firmly. On no account use force to get the detonator into position: it is particularly dangerous to screw or twist it.

Where the distance to the firing point is an inconvenient length, as in the case of a road mine, supplement the safety fuze with a length of F.I.D.

4. *Firing with F.I.D.*—To initiate detonation in F.I.D., one of the three methods shown in Plate **158,** Figs. 1, 2 and 3, should be used. Fig. 1 represents a metal union joint. The F.I.D. is inserted at one end and crimped and the detonator inserted at the other end and kept tight by the sliding band. The junction of fuze and detonator should be opposite the window to ensure that the end of the detonator is in close contact with the T.N.T. filling of the F.I.D. Unless this close contact exist, a failure will occur.

Fig. 2 shows three detonators tied tightly with twine or rubber tape on to the F.I.D., the safety fuze being inserted into one of the detonators. All three detonators should be touching each other and pointing in the direction of detonation.

Fig. 3 represents the F.I.D. tied tightly with twine or rubber tape on to a dry guncotton primer into which the detonator and safety fuze have been inserted.

Single junctions in F.I.D. may be made by any of the above three methods by substituting F.I.D. in each case for the safety fuze and detonator. Fig. 4 represents the guncotton primer method.

A junction of multiple branches of F.I.D. is best made by the method shown in Fig. **5.** The F.I.D. main is threaded through three dry guncotton primers and the requisite number of branches tied tightly along the outside of the primers by twine or rubber tape. A possible alternative method is by means of a junction box filled with ammonal or similar high explosive into which the ends of the F.I.D. are led. To ensure success, however, with this method, it is necessary to tie two detonators to the end of each F.I.D. branch inside the junction box, the detonator pointing in the direction of detonation.

In the use of F.I.D. generally, it is useful to remember that F.I.D. will detonate dry guncotton and dry guncotton will detonate F.I.D., in each case without the necessity for using a detonator.

5. *Misfires.*—

i. *Causes of failure with safety fuze or F.I.D.:*—

(*a*) The fuze itself defective. Use only fresh fuze in good condition.

(*b*) The detonator may fail to detonate the primer owing to bad contact between the detonator and primer (*see* Sec. **109**, 2) or to a faulty primer.

(*c*) The composition at the end of the fuze may become inert owing to moisture.

When a charge is to be left long in position allow for cutting off 6 in. of the fuze before firing. The connection between F.I.D. and safety fuze should not be made until it is intended to fire.

(*d*) Defective joints in the safety fuze or F.I.D.

ii. *Causes of failure with electrical firing:*—

(*a*) Broken leads. Do not subject leads to any undue strain at any part of the circuit, especially at joints and where cables pass through tamping or round corners. Protect by burying: 2 ft. deep splinter-proof: 7 ft. deep shell-proof.

(*b*) Defective joint or partly broken cable causing high resistance (*see* Sec. **110**, 2).

(*c*) Bad insulation of cable or joints causing leakage of current.

(*d*) Faulty exploder (*see* Military Engineering, Vol. IV).

(*e*) Defective detonator. A broken wire bridge would be detected by the continuity test. Detonators may be over or under sensitive (*see* Military Engineering, Vol. IV).

(*f*) Failure of detonator to detonate primer.

iii. *Treatment.*—If misfire occurs, the longest possible time should be allowed to elapse (at least half an hour) before the charge is approached. In accessible places, the charge should be "killed" by detonating a fresh charge as close as possible to it. The charge should only be withdrawn when there is no alternative, as its removal will be a dangerous operation. In such cases, the tamping in proximity to the detonators must be carefully removed, the whole being previously drenched with water, and the detonators withdrawn at the earliest opportunity.

The following procedure with regard to misfires has been followed with success :—

After waiting half an hour, tie a 25 yards length of string to the end of the fuze. Pull, and generally the fuze and detonator will come out together.

111. Making up and fixing charges

1. *General principles.*—It must be clearly understood that high explosives, particularly when used untamped, have a very local effect. In the case of a small concentrated cutting charge not much effect will be produced beyond the portion of the object to be destroyed with which the charge is in actual contact. It is thus essential that with rapidly acting high explosives such as guncotton the charge should be spread across the whole width of the object to be cut, and not concentrated in one spot.

For example, a charge placed concentrated against one spot in a wall would be certain to blow a breach in that wall, whereas the same charge spread over the appropriate length would cause that length to fall.

The following points are important :—

i. All portions of the charge must be in close contact with each other, or else must have separate points of detonation.

ii. The charge must cover the whole surface to be destroyed, and be in close contact with it.

iii. The charge as a whole must be firmly fixed to the object to be destroyed.

iv. All points of detonation must be firmly secured.

2. *Guncotton charges.*—A primer must invariably be used with charges of wet guncotton. It should fit tightly in the hole provided for it in the guncotton slab. A detonator with primer, buried in a concentrated charge, will detonate all explosives within a radius of 4 ft. For an extended charge at least one point of detonation for each 10-ft. run must be provided. Close contact between slabs is essential.

In making up guncotton charges for demolishing walls, arches, etc., the slabs may often be lashed to a board which can be firmly fixed to the object to be destroyed. A hole is drilled in the board to enable the detonator to be inserted from the opposite side.

Timber packing and mud or clay may be used to secure

close contact when fixing guncotton charges to girders or other objects.

The " bag, guncotton, 5-lb.," (or 25-lb.), which is an article of store, is used for demolitions under water or in damp places. It is a waterproof bag with a wide mouth, provided with a wooden clamp for sealing it. The wooden clamp has two grooves cut in it, to permit electric leads or safety fuze being passed into the bag. Waterproof bags to contain 25 lb. of explosive form part of the equipment of engineer field units.

3. *Ammonal charges* may be fired by detonating—

i. A slab of guncotton fixed in close contact with a portion of the charge.

ii. Two or three turns of F.I.D. wound round a tin of ammonal.

iii A detonator and primer buried in a portion of the charge, a waterproof bag being used as a container if in a damp place.

Ammonal reacts chemically with copper and will gradually eat away the tube of a detonator made of copper, making it dangerous to withdraw it after any length of time. Unless the charge is to be fired at once, therefore, method (iii) should only be used after wrapping the detonator and primer in oiled silk.

In emergency, a detonator without a primer is sufficient to detonate ammonal, but the explosive effect obtained may not be so great.

In large charges leave the ammonal in the tins in which it is issued. The ammonal will detonate through the thin walls of the tins, provided they are packed in close contact.

For small charges ammonal may be placed in sandbags or waterproof bags. For rails and girder demolitions preserved beef or tobacco tins often make suitable containers. For certain demolitions, *e.g.* trees, piles, the charge may be placed in a tube of strong canvas : such a charge has the merit of flexibility. For large boreholes, stove-piping joined together, and, if necessary, waterproofed, makes an excellent container. A 6-in. pipe will take about 16 lb. of ammonal for each ft. run.

4. *Dynamite charges.*—A detonator or commercial cap is sufficient to detonate dynamite. Unfold the paper covering containing the cartridge, and make a hole in one end of the cartridge with a piece of wood the same size and shape as the detonator. Insert the fuzed detonator in the hole and tie the

end of the paper firmly round the fuze to hold the detonator in position. (*See* Plate **155**, Fig. 2.)

If dynamite requires ramming, as in a borehole, squeeze each cartridge gently into place with a wooden rammer, placing the fuzed cartridge in last, but do not ram it. The use of an iron bar for ramming is dangerous.

Avoid pushing the detonator so far into the cartridge that the safety fuze may set fire to it before firing the detonator. About one-third of the copper tube of the detonator should be exposed outside the cartridge.

5. *High explosive shell*, when used as demolition charges, should be prepared for firing as follows. Unscrew the fuze or plug: this requires great care, especially in the case of fuzed shell. Spanners, especially made for the purpose, which enable a good leverage to be obtained, should be used. Hitting the fuze with a hammer or wooden mallet to loosen it is dangerous. Remove the fuze, and substitute a fuzed detonator and primer, buried well in the explosive.

An alternative, but less reliable, method of firing is to detonate a slab of guncotton fixed against the shell. The detonation of one of a group of shells placed in close contact may be sufficient to fire the whole charge.

6. *Portable charges*.—Conditions do not always permit of the charge being made up on the spot, as for instance, in a raid. If detailed information is available, the form of the charge can be adapted to suit the objective. Normally the charge should be made up in box form of size and weight (not exceeding 25 lb.) suitable for one man to carry without difficulty. It should be provided with a stout handle and two or more separate means of ignition by fuze. Patent lighters, being quicker to operate than matches, are a suitable means of ignition for portable charges, but matches or fuzes should be carried in addition.

25-lb. tins of ammonal may be adapted for portable charges by fitting a container for an igniter set (Military Engineering, Vol. IV, 1934, Plate 23). Charges made by placing several such tins in contact would be fired by firing the igniter set of one tin.

7. *Tamping*.—The tendency of all explosives is to act along the line of least resistance. Tamping is material placed round the charge in order to increase the explosive effect. Sandbags with earth are usually used. High explosives in close contact with the objective, as in cutting charges, are rapid enough in action to cut it when untamped, though tamping will increase the effect. Tamping is, however, essential in mined charges. The gallery should therefore be tamped for a distance equal to twice the line of least resistance.

8. *Precautions in fixing detonators, etc.*—Precautions must be taken to see that no strain can be conveyed by the fuze to the detonator as this might displace it or fire it prematurely. In charges not requiring a container, fix the fuze or electric leads securely 3 or 4 inches from the detonator. Where a bag container is used lash a small piece of stick at right angles to the fuze or leads just inside the bag. Double the electric leads back outside the bag and lash them firmly to it. Fuzes must be secured to some object outside the bag. (*See* Plate **159**.) Lengths of safety fuze leading to an exposed charge should be fixed lightly or weighted to prevent the lighted fuze curling up and setting fire to the charge prematurely.

The severe jerk set up in the F.I.D. on detonation tends to displace it, so secure the fuze firmly throughout its length and especially to the charges it is to detonate. Lengths of F.I.D. close to each other should be separated by a board. One length of fuze may otherwise cut the other without detonating it.

9. *Protection of charges*.—Charges exposed to the weather should be protected against damp and sun. This protection can be obtained by enveloping the charge in oiled silk or linen; alternatively, a board or piece of tarpaulin cover can be used. To prevent damp reaching the detonator and primer, enclose them completely in oiled silk, and tie them securely before inserting in the slab.

If F.I.D. is used, insert the end into the detonator and primer, enclosing the whole in oiled silk.

In electric firing, the detonator may be inserted into the primer, enclosing the whole in oiled silk.

Similar precautions should be taken with mined charges left in position for any length of time.

The tins in which ammonal is issued afford sufficient protection in most cases, but in wet situations stouter containers such as petrol tins, should be used. The charges may, alternatively, be placed in waterproof bags or sealed vessels.

To prevent deterioration of safety fuze from damp, delay fixing it, if possible, till the charge has to be fired. When large mined charges are to be fired by F.I.D., lead this fuze, if possible, beyond the tamping at the foot of the shaft, but do not connect up the primers, detonator and safety fuze until the time of firing. Keep these in sealed tins close at hand.

Charges under water may be enclosed in "bags, guncotton, waterproof," or in earthenware or metal tins, such as petrol tins, sealed with pitch.

112. Precautions to be observed when firing charges

1. When a demolition is to be carried out under fire, spare men should be detailed to replace casualties, and every man should have the means of lighting the charge and should know exactly what is to be done and the means available.

2. In carrying out demolitions under peace-time conditions surplus explosives, detonators, etc., should be removed to a place of safety and sentries should be posted to prevent unauthorized persons from coming within the danger zone. In this connection it is well to remember that, in demolishing metallic substances (guns, girders, rails, etc.), the fragments are liable to be blown 1,000 yards or more away. When possible, experimental demolitions of this nature should be carried out in a pit or behind a wall of sandbags. In the case of large mined charges in soft soil, 300 yards may be taken as a safe distance from the explosion. If, however, the surface is hard or frozen, or there is a high wind, debris may be hurled up to 600 yards away from the explosion.

113. Classification and calculation of charges

1. *Classification of charges.*—Charges may be divided into three main classes:—

i. *Cutting charges.*—The explosive is placed superficially and acts chiefly through shattering action at the instant of detonation.

ii. *Mined and borehole charges.*—The explosive may be buried within a suitable medium which forms efficient tamping, and enables the main effect to be obtained by the lifting action due to the expansion of the gases on explosion.

These charges may be sub-divided, according to the method by which they are prepared, into:—

(*a*) *Mined charges*, laid in chambers commonly made by mining or digging in soft to medium soils but also by cutting into masonry, such as piers and abutments, or by exploding a small charge at the end of a borehole.

(*b*) *Auger-hole charges* laid in holes made by earth augers or special boring machines in soft to medium soils.

(*c*) *Borehole charges* laid in boreholes drilled by hand or power tools in timber, masonry or rock.

iii. *Concussion charges.*—A modified form of mined charge in which an enclosed air space replaces solid tamping and the lifting action of the explosive takes effect through the pressure of the air on the containing walls.

2. *Calculation of charges.*—A summary of the formulae used for the calculation of charges is given in tabular form in Table 15. These formulae include a factor of safety to cover unforeseen irregularities that may occur in the strength of materials, explosive, etc. Charges should not be reduced below the figure arrived at by calculation and, if fixed hastily, to allow for errors due to hurried calculations, improper contact, etc., the charge must be increased according to circumstances up to 100 per cent.

114. Cutting charges

1. *Iron and steel work.*—The use of guncotton only is considered. Similar principles apply when other high explosives are used.

Since the charge must extend over the whole width to be cut, the minimum charge is one slab for every 6 in. of breadth. One slab for every 6 in. will cut metal 1 in. thick, and one slab will cut a first class steel rail (Plates **159** and **160**).

2. *Girders and plate girders.*—Owing to the variety of type no general rule can be laid down. The following principles must be followed: Calculations. *Flange.*—Use the formula $\frac{bt^2}{8}$ where b is the breadth and t the thickness, both in inches.

Web.—Allow for the whole length between flanges. If the thickness is under 1 in., allow 1 slab for every 6 in.; if over, use the formula $\frac{bt^2}{8}$.

In calculating a riveted plate, the thickness t = the thickness of all the plates plus the height of the rivet heads on one side.

In calculating a built-up girder, in order to avoid any detailed measurements and calculations, the flanges are usually taken as being their maximum thickness, *i.e.* (plate + angle + rivet head) over their whole width and the web is measured at its thinnest part, rivets and angles being neglected. The results, whilst not strictly accurate, are sufficiently so for all normal types of girder.

Where the guncotton slabs are placed across a projection, the spaces between the charge and the metal must be filled with clay, etc.

Where the charge is not placed over the whole width of metal to be cut, it must be doubled. This applies to both flange and web.

The normal method of fixing charges is shown on Plate **159**, Fig. 1. An alternative is shown on Plate **160**.

Example (Plate **159**, Fig. 1, refers.)

Web.—Thickness of web = ⅜-in., *i.e.* under 1 in.
$\therefore$ one slab for every 6 in. will suffice.
Length of web between flanges = 35 in.
$\therefore$ No. of slabs required for web = 6.

Top flange.—Maximum thickness $t = \frac{1}{2}$ in. (flange) + $\frac{1}{2}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{1}{2}$ in. Breadth $b = 15$ in.

$$\therefore \frac{bt^2}{8} = \frac{15}{8} \times \left(\frac{3}{2}\right)^2 = 4{\cdot}2 \text{ lb.}$$

Double the charge as above.
$\therefore$ Charge required = 8·4 lb., or 9 slabs.

Bottom flange.—Maximum thickness $t = \frac{1}{2}$ in. (flange) + $\frac{5}{8}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{5}{8}$ in.
Breadth $b = 15$ in.

$$\therefore \frac{bt^2}{8} = \frac{15}{8} \times \left(\frac{13}{8}\right)^2 = 5 \text{ lb.}$$

Double the charge as above.
$\therefore$ Charge required = 10 lb., or 10 slabs.

3. *Braced girders.*—Select a suitable point on the girder at which to cut through all the members.

Calculate charges for each member from formula $\frac{bt^2}{8}$

4. *Rails, guns and cables.*—

i. *Rails.*—A good method is shown on Plate **161**.

ii. *Guns.*—The most effective point of attack is the breech. If a short length of the muzzle is blown off, it may be possible to use the piece again either as a howitzer or as a gun of shorter range.

The number of slabs of guncotton required for a demolition, prepared under hasty conditions, may be determined by squaring the calibre of the gun in inches; but, when time is available for careful preparation, three-quarters of that figure may be taken.

Guncotton is, however, an unsuitable explosive owing to the difficulty of packing it neatly; if dynamite or ammonal is available and the charge is properly packed so that there are no voids and good contact is obtained, 8 oz. of dynamite or 1 lb. of ammonal may be taken as the equivalent of 1 lb. guncotton.

The charge may be considerably further reduced for older or less powerful weapons, and for howitzers it may be halved. The gun should first be loaded with a shell; if no shell is available 2 or 3 ft. of the bore should be tamped with earth. The demolition charge is then packed close behind the shell or earth tamping, and the remaining space in the chamber filled with earth. The breech is then closed as far as possible, just allowing room for the safety fuze or electric leads. With guns of large calibre it is preferable, if possible, to close the breech completely, and fire the charge through the vent tube.

When the muzzle end of a piece is selected for attack, about half the amount of guncotton required for the destruction of the breech will suffice, provided that the charge is well tamped on both sides. The charge should be made up in the form of a cylinder of diameter about an inch smaller than the bore.

If the explosive in bulk is not available, an alternative but less reliable method of destruction is to detonate a high explosive shell in the breech after first blocking the bore.

A gun may be rendered temporarily useless without the aid of explosives by carrying off the breech block and sights, or attacking it with a sledge hammer. In the latter case, the threads of the breech block should be burred, the breech mechanism strained, and recoil buffers dented.

iii. *Cables.*—If under 4 in. circumference one slab is sufficient. For cables up to 8 in. circumference place the charge on one side of the cable. If four or more slabs are required place equal portions of the charge staggered on opposite sides of the cable to produce a shearing action. As much of the surface of the slabs as possible should be in contact with the cable, to which they should be firmly secured.

5. *Masonry, brickwork and concrete.*—Where great rapidity [illegible] required use cutting charges.

i. *Piers.*—It should be rarely necessary to resort to cutting charges, owing to the large quantity of explosive involved, but, where time is very short and explosives plentiful, piers up to about 3 ft. may be demolished in this manner. Place the charge on one side only.

ii. ***Arches.***—The charge should be laid touching the masonry in a trench which is afterwards filled in, or may be fixed to a board secured to the under side of the arch. The board should be strutted if possible, but must otherwise be trussed. A disadvantage of this method is the difficulty of getting the charge into position. In this case the thickness T must be taken as thickness of masonry plus that of material above it. Greater damage results by attacking the haunches than the crown (Plate **159,** Fig. 3).

iii. ***Reinforced concrete.***—Since the explosive cannot be placed in actual contact with the steelwork much of the shattering effect is absorbed before the steel is reached. If possible reinforced concrete should be demolished in stages. First place a charge of 4 slabs for every ft. run across the surface believed to be nearest the reinforcement, which is then cut by a charge calculated on formula $C = 2/3d^2$ if the bars are free. If they still adhere to the inner concrete treat as bars of double the diameter.

In the case of thin slabs a charge of $20BT^2$ may be used in one operation, but the results are always uncertain.

115. Mined and borehole charges

1. *Road cratering.*—Mined charges can be laid by :—

i. Regular mining operations, shaft, gallery and chamber being excavated.

ii. Drilling boreholes.

A mine crater makes a formidable obstacle in a road or railway, particularly where deviation is difficult. It is, however, a deliberate operation requiring considerable quantities of explosive and much labour. The charge should be placed under the centre of the road or railway and calculated to form a crater large enough to remove the whole width of the permanent way or metalled surface. If water is near the surface or the road exceptionally wide, two or more charges may be necessary.

To lay the charge sink a vertical shaft by the side of the road and drive a horizontal or inclined gallery from the bottom of it to the required position (Plate **162,** Figs. 1 and 2). Excavate a chamber just large enough for the charge, preferably on one side of the gallery to increase the tamping effect. If the site is an embankment, or if the cellar of a house by the roadside is available, the shaft may be dispensed with. The methods of constructing shafts and galleries are given in Chapter V. Temporary shoring for shafts can be made from X.P.M. or C.G.I. and timber.

Place the priming charges containing the detonators in waterproof bags, even in apparently dry soil, unless the mine is to be fired immediately. Take the firing cables or fuzes along the roof of the gallery, preferably fastening by string tied to nails driven in the timbers. If staples are used take great care not to damage the leads. Electric cables and F.I.D. should be kept separate, *i.e.* placed on opposite sides of the gallery. Then tamp the gallery solid with sandbags for a distance equal to three-quarters the diameter of the crater to be formed, or up to the foot of the shaft.

Approximate rates of progress are given in Appendix V.

Calculate mined charges for roads by the formula given in Table 15. For a concrete foundation or heavy soling increase the charge by 50 per cent. The depth of the charge should be between $\frac{D}{6}$ and $\frac{D}{2}$. $\frac{D}{4}$ is the most satisfactory depth.

ii. *Rapid road cratering.*—Road craters can be quickly made by the following method.

The road crust is broken through by power or hand tools or by firing successive surface charges. A 2 to 3-in. diameter length of piping fitted with a spear-head and driving cap is then hammered into the ground to the required depth.

A small charge of a few ounces of gelignite or guncotton primers is fired to form a chamber for the main mine charge.

The main charge of ammonal is finally poured into the camouflet chamber and fired.

It has been found that a main charge of 80 lb. of ammonal at a depth of 6-ft. will form a crater from 25 to 30-ft. diameter with a depth of about 8 ft.

The whole operation can be carried out by a party of one N.C.O. and four men in about an hour.

The following points should be noted when carrying out this method :—

(*a*) Accidents have occurred in industrial work during the loading of the main charge. These have been attributed to the presence of smoulding residues in the camouflet chamber. The relative risk will vary according to the type of explosive used and it is thought to be greatest with gunpowder and least with ammonal. Whilst it does not appear that the risks of prematures are sufficient to affect the use of the camouflet method in war, in peace special precautions should be taken. These will depend on circumstances: a little sand might be emptied into the camouflet chamber; wiping out with a damp rag might be practicable; a pause between the blowing of the camouflet and the loading of the main charge might enable any residue to burn itself out. Safety fuze should not be used below ground level.

(*b*) Once the road crust has been broken and the pipe driven to the necessary depth it is not essential for the pipe to remain in the hole while the camouflet charge and main charge are introduced and fired. In normal soil the pipe may be withdrawn and the camouflet fired without risk of loose earth filling in the hole.

(*c*) If necessary, speed of filling the main charge can be increased by enlarging in the following way the hole driven by the pipe:—

After the pipe has been driven to the required depth, up to six lengths of F.I.D. may be lashed closely together and inserted in the hole with the camouflet charge of, say, guncotton primers threaded on to the end of one of the lengths of F.I.D. The effect of the detonation of the F.I.D. is appreciably to increase the diameter of the hole bored by the pipe.

2. *Mined charges in abutments, piers and walls.*—

i. *Abutments.*—Charges for mining bridge abutments are calculated similarly, the diameter of the crater being taken as the width of the abutment exclusive of the wing walls. If the abutments are faced with masonry use $\frac{D^3}{50}$. Place the charge $\frac{D}{2}$ to $\frac{D}{4}$ from the external face, the depth of the centre of the charge being one and a half times its distance from the abutment face, and for masonry bridges at least as deep as the springing of the arch.

Example.—(*See* Plate **162,** Figs. 3 and 4.)

Abutment 30 ft. wide. Charge $\frac{D^3}{50} = 540$ lb.

Distance 8 to 15 ft. from face of abutment.

Depth 12 to 23 ft. according to actual distance from face of abutment.

ii. *Piers.*—Masonry piers may be destroyed by a series of small mined charges. The holes for the charges are made either by hand using jumping or boring bars or by power tools. They should be not less than 9 in. by 12 in. as a smaller hole will take longer to make.

Calculate charge from formula $\frac{L^3}{6}$. Space charges at intervals of $\frac{4}{3}$L, the end charges being L feet from the end. Where, in the case of very wide piers, it is not practicable to place the charges in the centre L should be taken as the distance of the charge from the further face, but the ratio $\frac{OB}{OA}$ must not exceed $\frac{3}{2}$. (*See* Plate **162,** Fig. 4.)

To allow more room for men to work at the face charges may be placed alternatively from each side of the pier as in Fig. **3.**

Times taken to excavate holes are given in Appendix V.

Example.—(*See* Plate **162,** Figs. 3 and 4.)

For speed make holes minimum depth permissible, *i.e.* 2 ft. $\left(\text{Ratio } \frac{OA}{OB} \text{ is then } \frac{2}{3}\right)$, then L is 3 ft.

Charge required in each hole $= \frac{L^3}{6} = \frac{27}{6} = 4\frac{1}{2}$ lb., say 5 lb. guncotton.

Distance apart of charges is $\frac{4}{3}L = 4$ ft.

The number of charges works out at 7 when spaced out with the end charges 3 ft. from the end.

$\therefore$ Total charge $= 35$ lb.

A cutting charge for the same pier would have been $\frac{2}{3}BT^2 = \frac{2}{3} 30 \times 25 = 500$ lb.

Note.—If the pier is very thick it will be found that boring in two-fifths instead of half the width will result in very much larger charges being required. A balance must therefore be struck between speed and economy, depending on which is the more important.

3. *Auger-holes in earth.*—The introduction of mechanical tools in field units has greatly increased the scope of auger-hole charges, and frequently large savings of time and explosive can be effected by their use. The following are the most general types of auger-hole charges:—

i. Auger-holes in earth, such as charges in embankments, behind abutments, mined charges laid in marshy ground, or extended charges for forming improvised trenches. An earth auger or a helical or thrust borer will bore a hole up to 20 ft. in soft ground. A party of three men can work a 6-in. earth auger and carry it with its rods from place to place. The holes should be lined with metal tube or stove piping, and plugged if not immediately charged. The charges should be made up in waterproof tubes. A 6-in. hole will take 16 lb. of ammonal or 12 lb. of blastine for each ft. run.

Calculate concentrated charges as mined charges. For horizontal charges use the "D" formula, the bore to be at a depth between $\frac{D}{6}$ and $\frac{D}{2}$. Charges calculated from the "L" formulae will blow a gap approximately equal to 2L.

Auger-holes for laying charges under roads, etc. They may be bored vertically, or obliquely downwards, or from one side (at an embankment). With vertical borings, the surface and soling can be broken up by a pneumatic pick, and the subsoil excavated by an earth auger and miner's pick. Bores can be made quickly up to a depth of 6 ft., and the charge calculated from the "D" formulae for mined charges, the nature of the subsoil determining the formula used. Auger-holes may be placed side by side to obtain more concentrated charges. Such charges should be connected electrically in series, or by F.I.D. A similar demolition can be effected by driving a pile of water piping with a previously prepared steel point attached, inserting a charge in it and well tamping. The derrick of a 30-cwt. six-wheeled derrick lorry and a suitable monkey can be used for driving the pile. A charge of 3 lb. of ammonal laid 3 ft. deep will produce a crater 6 to 7 ft. or more in diameter in ordinary soils. Such a charge can be completed in 10 minutes. This method is particularly applicable to fords.

4. *Boreholes in rock and masonry.*—For full details of boring and blasting, *see* Military Engineering, Vol. IV.

Bridge piers, etc., may be destroyed by a series of borehole charges if power tools are available. If they are not it will usually be quicker to place a series of mined charges as described in para. 2, above.

The charges are calculated by the formula $W = L^3 \times \frac{5}{4}$,

where W = charge of dynamite in oz. (for other explosives, *see* Table 16). L = line of least resistance in feet measured from the centre of the charge to the more distant face.

i. The charge must not occupy more than two-thirds of the borehole. The possible size of the charge is therefore dependent on the diameter of the borehole as well as on its own length. To accommodate more explosive boreholes may be made in pairs. The quantities of explosive that can be loaded into boreholes of different sizes are given in Table 17.

ii. Neither end of the charge must be closer than 8 in. to the surface.

iii. The spacing of adjacent charges should normally be equal to L and must not exceed it.

iv. The formula is based on good brickwork or masonry or concrete *under load*, *e.g.* piers, arch rings, or heavily loaded abutments. The charge may be reduced by not more than 50 per cent. in all, where the masonry is of poor quality and/or there is little or no load on it.

v. A plastic form of explosive is the simplest for loading. Ammonal may be used in sloping holes, but it is very difficult to load in horizontal holes. In such cases it should be made up into cartridges of a diameter of ¼ in. less than the hole.

vi. The normal method of loading boreholes is as follows :—
The size of the 2-oz. cartridges in which dynamite or gelignite are usually issued is 3½ in. long by ½ in. diameter. In small boreholes insert the cartridges one at a time and in long ones tie two or more together according to diameter.

Each cartridge or bunch of cartridges should be gently rammed home with a wooden rammer. Never use an iron implement for the purpose. Do not exert undue force.

The cartridge containing the detonator should be inserted last and must be in close contact with the remainder of the charge but must *not* be squeezed home.

vii. The holes should be tamped with dry sand if available. Eight to 12 in. is sufficient, placed immediately above the explosive, but *not rammed*. Failing sand use damp clay or mud *gently* rammed.

viii. Where piers, etc., are rubble-filled, it may not be possible to keep boreholes clear and it will then be necessary to resort to small mined charges.

In the larger holes required for this purpose, if the rubble does not form an arch, it will have to be strutted up.

Example.—In the case of the pier in Plate **162**, Fig. 3.
Depth of borehole, say, 2 ft.
L.L.R. is then, say, 3 ft. 4 in. (allowing for the charge).
Charge is then $\frac{5}{4} \times 3\frac{1}{3}^3$ (dynamite) $= \frac{5}{4} \times \frac{1000}{27}$, say 46 oz.

From Table 17, 3½ lb. can be packed into 1 ft. of 2½-in. borehole, so 46 oz. will take $12 \times \frac{2}{7} \times \frac{46}{16}$ in. = 8½ in. approx.

Number of charges required is $\frac{30}{L} - 1 = 8$.

Total weight of dynamite is 46 × 8 oz. = 23 lb.

This compares with 500 lb. guncotton for a cutting charge and 35 lb. guncotton for a series of mined charges, for the same pier.

5. *Delay action mines* are operated by a delay action fuze, by means of which the time of the explosion, after the charge has been laid, may be deferred for a period varying from a few hours to several weeks or even months. The simplest and most satisfactory type of delay action fuze hitherto invented depends on the dissolving of a fine steel wire by a corrosive liquid; the length of the delay is regulated by varying the strength of the liquid. It is fully described in Military Engineering, Vol. IV.

Delay action mines will, as a rule, consist of charges of several hundred pounds laid at depths suitable to form large craters. They are especially suitable for laying in the permanent way of railway lines, bridge abutments, etc, with a view to causing intermittent interruption of road and rail communications, after the damage effected by ordinary demolitions prior to the retreat has been repaired by the enemy. They may also be laid with success in billets, dug-outs, etc., which the enemy is likely to occupy, and in abandoned shell dumps. In the latter case difficulty of detection may be increased by the container of the delay action fuze being constructed to resemble an ordinary shell fuze.

116. Concussion charges

1. *Concussion charges* are principally employed where an air space can be enclosed, as in buildings.

2. For buildings subdivide the charge into equal portions, place in the corners and against any supporting pillars and fire simultaneously.

Example.—Heavily reinforced concrete machine gun emplacement.

Walls 3 ft. thick, floor area 30 f.s.

Take K = 10.

$$C = K\frac{AT^2}{10} = 10\frac{30 \times 3^2}{10} = 270 \text{ lb.}$$

For thin walls use the formula $m\frac{V}{100}$.

TABLE 15.—CALCULATION OF CHARGES

Summary of formulae

In the following formulae, unless otherwise noted in the remarks column:

B = Width of object attacked, *i.e.*, length of charge, in feet.

b = Width of object attacked, *i.e.*, length of charge, in inches.

T = Thickness of object attacked, in feet.

t = Thickness of object attacked, in inches.

c = Circumference of object attacked, in inches.

d = Diameter of object attacked, in inches.

D = Diameter of crater, in feet, or width of crater in extended charges.

L = L.L.R., in feet.

1. *Cutting charges.*—

Explosive used: guncotton, or explosives of equivalent shattering power, *e.g.*, dynamite No. 1, or gelignite. If another explosive is used, the charges must be multiplied by the factor give in Table 16. Charges untamped.

Object attacked	Charge in lb.	Remarks
Iron or steel rectangles.	$\frac{1}{8} bt^2$	A slab of guncotton will cut a steel plate 1 in. thick.
Iron or steel rounds.	$\frac{2}{3}d^2$ or $\frac{C^2}{16}$	A slab of guncotton will cut an unsupported bar of 1¼-in. diam. or cable of 4-in. circumference.
Masonry walls.	$\frac{1}{2}BT^2$	The length of breach B must not be less than the height of wall. Two slabs of guncotton per ft. run are sufficient for walls 2 ft. thick.
Masonry piers.	$\frac{2}{3}BT^2$	
Masonry arch-rings.	$\frac{3}{4}BT^2$	If attacked from above. If attacked from below, include in the figure taken for T half the thickness of the filling in the case of a metalled road and one-quarter where the filling is not consolidated, but with a maximum value for T of twice the thickness of the masonry of the arch-ring.
Reinforced concrete. Thin slabs.	$20BT^2$	For other forms, bare the reinforcement and cut bars separately.
Timber, hardwoods :—		
Rectangular section.	$3BT^2$	Where D is diameter in ft. For soft woods these charges may be halved.
Circular section.	$3D^3$	

2. *Mined and auger-hole charges.*—

Explosive used : ammonal. If other explosives are used the charge must be multiplied by the factor given in Table 16. Charges tamped.

Object attacked	Charge in lb.	Remarks
Mined charges in :—		
Rock and masonry.	$\frac{D^3}{50}$ or $\frac{L^3}{6}$	For detailed formulae used in mining, *see* Military Engineering, Vol. IV, 1934, Chapter XIV.
Medium and soft soils.	$\frac{D^3}{100}$ or $\frac{L^3}{12}$	
Made ground.	$\frac{D^3}{200}$ or $\frac{L^3}{24}$	
Auger-hole charges in :—		
Rock and masonry.	$\frac{D^2}{25}$ or $\frac{L^2}{6}$	Per ft. run.
Medium and soft soils.	$\frac{D^2}{50}$ or $\frac{L^2}{12}$	
Made ground.	$\frac{D^2}{100}$ or $\frac{L^2}{24}$	

3. *Borehole charges.*—

Explosive used : dynamite or blasting gelatine. If another explosive is used, the charge must be multiplied by the factor given in Table 16. Charges tamped.

Object attacked	Charge in oz.	Remarks
Masonry.	$L^3 \times \frac{5}{4}$	L measured to centre of charge, which must not occupy more than two-thirds of a borehole, or be within 8 in. of surface.
Masonry, long extended charges.		As for auger-hole charges, when conditions are similar.
Timber.	$6D^2$	D = diameter (or side) of baulk in ft.

4. *Concussion charges.*—

Explosive used : gun-cotton, dynamite, blasting gelatine or ammonal. Charges must be doubled if apertures are not blocked.

Object attacked	Charge	Remarks
Masonry buildings, etc.	$K\frac{AT^2}{10}$	A is the area of internal floor-space in sq. ft. T is the thickness of walls in ft. Values of K are as follows :— Mud walls, inferior masonry, 1. Good masonry, 2. Reinforced concrete, 4 to 10.
Structures with thin walls.	$m\frac{V}{100}$	V is volume of enclosed air-space in cu. ft. Values of *m* are as follows :— Weak wooden sheds, 1 to 2. Corr. iron structures, 4 to 8. Stout wooden buildings, log huts, etc., 6 to 12. Strong steel casing (*e.g.*, armoured car or tank), 20 to 30.

5. *Miscellaneous demolitions.*—

Object attacked	Details of charge, etc.
Guns, modern, long range.	Use charge of d^2 slabs in breach or half that at muzzle, where d is bore of gun in inches. For older pieces charges may be reduced.
Howitzers.	Half the charge for a gun. N.B.—In both the above, when time is available for careful preparation, 8 oz. of dynamite or 1 lb. of ammonal may be used instead of one slab of guncotton.
Stockades.	Earth and timber, 4 lb. a ft. run. Steel rails, 7 lb. a ft. run.
Water tanks.	Submerged charge of 1 slab for each 100 cu. ft. of capacity.
High-explosive shell.	One slab may detonate a shell. One shell detonated in a pile may detonate the rest.

6. *Masonry towers as encountered on N.W. Frontier of India.*—

Object attacked	Detail of charge, etc.
i. Tower with roof where access can be had to inside of tower. Four walls or circular wall. No solid base.	Charge = 10L lb. Placed in centre of tower. (L = width or diameter of base in ft.)
ii. As above but without roof.	Four charges each ½L lb. placed in the corners in an excavated hole.
ii. Towers with solid base and roof, whether attacked from outside or inside.	Charge = 4L lb. dug down into solid base.
iv. Towers with solid base, roof and internal staircase.	Charge = 9L lb. dug down into one side of solid base.

TABLE 16.—FACTOR BY WHICH CHARGE AS CALCULATED MUST BE MULTIPLIED

Explosive used (close packed unless otherwise stated) (1)	Cutting charges (2)	Mined charges		Borehole and blasting charges (5)
		In soft and medium soils * (3)	In rock, etc. (4)	
Ammonal	2·0	1·00	1·00	1·6
Amatol	2·5	1·25	1·25	2·0
Alumatol	2·4	1·19	1·19	1·9
Dynamite No. 1	1·0	—	0·6	1·0
Guncotton	1·0	—	0·75	1·25
Guncotton, dynamite, etc., with with 25 to 30 per cent. air space in chamber	—	1·07	—	—

TABLE 17.—WEIGHT OF AMMONAL THAT CAN BE PACKED INTO VARIOUS DIAMETERS OF BOREHOLES

The following table gives the approximate weight of ammonal a ft. run for various internal diameters of cylinder, taking the weight of 1 cu. ft. of tightly packed ammonal as 82·5 lb. These figures should be reduced slightly to allow for voids when it is not possible to pack the ammonal tightly in the cylinders.

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* The factor in Col. 3 for soft and medium soils must be used for charges behind masonry abutments, if actually laid in such soils. It must also be used for auger-hole charges.

Internal diameter in inches (1)	Weight a ft. run in lb. (2)	Internal diameter in inches (3)	Weight a ft. run in lb. (4)
2	1·8	6½	19·0
2½	2·8	7	22·0
3	4·0	7½	25·0
3½	5·5	8	28·8
4	7·2	8½	32·5
4½	9·1	9	36·5
5	11·2	9½	40·6
5½	13·6	10	45·0
6	16·2	—	—

The following approximate weights of dynamite or similar explosive can be loaded into one ft. run of borehole of the diameters shown :—

Diameter of hole in inches	1	1½	2	2½	3	3½
Weight in lb. a ft. run ...	½	1¼	2¼	3½	5	7

117. Types of demolition

1. *Bridge demolitions.*—

i. In deliberate demolitions, attack :—

(*a*) Abutments, using mined charges, calculated as in Sec. **115**. The aim should be to make the destruction so complete that another bridge erected at the same site would be of much longer span.

(*b*) Intervening piers, if any. (*See* Sec. **114** and **115.**)

(*c*) The girders. In bridges of long span, cutting the main girders will probably be sufficient to cause collapse, but if the span is short, as in the case of a bridge over a road, the superstructure may prevent the bridge from falling. In this case, all the longitudinal members should be attacked to form a complete cut across the bridge. No definite rule can be given owing to the variation in design of bridges, but in cases of doubt all the members should be attacked. The cut should be near the centre of the span to prevent any portion of the bridge being used again.

d) The bridge approaches.

ii. In hasty demolitions, attack the girders or arches. It may often be possible to lay borehole charges in the abutments or piers.

iii. Mined charges may be quickly laid in abutments by blowing a preliminary charge, up to 50 lb., to form a cavity for the main charge.

Bridges in some continental countries have demolition chambers built in the abutments.

Where the approach is an embankment, auger-holes may be bored behind the abutment masonry and filled with ammonal charges in stove-piping.

iv. Timber bridges, of timbers up to 9 in. by 3 in., may be soaked with tar or petrol and burnt.

Underneath the roadway at the centre of each bay, are suspended thin sheet-iron trays, on which is put a little tar, petrol, cotton waste or other combustible matter. The latter are then fired. If this is impossible, the road bearers of two or three bays should be attacked with guncotton in a similar way to the demolition of girders. The slabs should be placed against the sides of the road bearers, and not on top, and the whole breadth to be cut must be covered.

Wooden piles may be destroyed by placing dry guncotton primers in auger-holes or by binding a necklace of primers round them.

v. For method of destroying suspension bridge cables, *see* Sec. **114,** 4.

vi. Reinforced concrete bridges need special treatment, *see* Sec. **114,** 5.

2. *Blocking roads.*—A road is most effectively blocked by a crater or series of craters. The larger the diameter and depth of the crater the more effective the obstacle, but if time does not permit of laying mined charges to form one or two large craters, an effective obstacle can be made by a series of shallow charges whose craters overlap. Craters which fill with water are particularly valuable.

For methods of forming craters by mining, *see* Sec. **115,** 1, i, by the camouflet method, Sec. **115,** 1, ii; by auger-holes, Sec. **115,** 3.

Suitable sites for craters are :—

i. *Abutments of road bridges,* particularly where a long embankment leads up to the bridge, and where the stream or gap forms a considerable obstacle.

ii. *Road embankments or road cuttings.*—Form two craters, one at each end. If culverts are made use of, protect the charge against water. The blockage of culverts may form useful inundations.

Where 6-in. boring machines are available, an embankment can be attacked by a long hole nearly parallel to the road with cover up to 15 ft., charged as described for boreholes. The road will be destroyed along the entire length of the charge.

iii. *Roads on a steep hillside.*—The charge should be calculated to blow out horizontally as well as vertically.

iv. *Causeways* over marshy ground. Use charges in boreholes.

v. *Where a pond runs alongside the road.*—The crater should be just clear of the pond, so that the water will not be blown out of it, but will drain into the crater.

vi. *Cross-roads and road junctions.*—Where a deviation would be difficult, or cause congestion of traffic.

vii. *Woods,* where deviations would cause considerable labour.

viii. *Level crossings.*—Only by arrangement with the representative of the D.G.Tn.

ix. *Fords.*—A piled charge may be laid in water piping, as described in Sec. **115,** 3.

Obstacles may also be made by felling trees across the road, a method particularly effective in a cutting.

3. *Destruction of railways.*—

i. *Tunnels.*—A length of 15 to 25 yards of the crown of the arch ring should be destroyed. The charge is calculated as for arched bridges. An obstruction may be made by derailing a heavy train or by causing a collision in the tunnel.

ii. A good method of destroying rails is shown on Plate **161** but rails can be quickly repaired and the best method is to attack bridges and culverts and railway installations such as water towers, workshops, sidings and signals and telegraphs.

10. *Miscellaneous.*—

i. *Barbed wire.*—In hasty demolitions a Bangalore torpedo may be used. It consists of a pipe, 2-in. or over in diameter, made of iron, stout zinc or tinplate, filled with ammonal, and pushed into the entanglement just above ground level. A fuzed detonator and primer are laid in one end, and the ends closed with wooden plugs, a hole for the safety fuze being made in one plug. If the torpedo is over ten feet long, a piece of F.I.D. should be run through the length of the charge. The length of the torpedo must be sufficient for it to project on each side of the entanglement.

ii. *Timber, posts, trees, etc.*—The most economical method is by boring one or more auger-holes to just beyond the centre, and inserting a charge of $\frac{3}{8}T^2$.

iii. *Piles.*—These may be cut off under the water as follows : The waterproofed charge is attached above water to the pile by a piece of wire rope wound loosely round it so that the whole charge will slide down the pile. A stick up which the fuze or leads are led is attached to the rope ring, and the charge is pushed down below water into position at the place where the pile enters the ground.

iv. *Shells and bombs.*—Place in a deep trench to minimize the risk of flying splinters, and detonate a guncotton charge in contact with them. Place the charge on top of the shell or bomb to be destroyed.

v. *Explosive.*—Search the material for loose detonators, spread in a thin line, and ignite at the down-wind end. Petrol or paraffin will assist the conflagration. If the explosive will not burn, scatter it over the ground. Do not throw it into ponds or wells as it may poison the water.

vi. *Tanks.*—The engine of a tank may be rendered useless in a similar manner to that of a car. Two or three pounds of explosive detonated on the engine will render a tank useless to the enemy.

The sides of a tank may be blown out, so that it may offer no protection, by a concussion charge, m being taken as 30

The demolition of derelict tanks causing an obstruction in roads, etc., may often have to be undertaken The sides should be blown out in the manner described above, and the shell then broken up by means of suitably placed cutting charges into pieces sufficiently small to be removed.

vii. *Cars and lorries.*—The destruction of the engine of a motor car or lorry presents little difficulty.

A few well-directed blows in the vital parts (radiator, magneto, crankcase, etc.) or a few pounds of explosive detonated on the cylinders, will suffice.

The wheels, axles, and girders of the chassis should be broken, the petrol tank pierced and available petrol poured over the body which should be set alight. Cars can be quickly disabled by the removal of the magneto and carburettor or by cutting the tyres.

viii. *Reservoirs.*—Destroy by mined charges in the walls.

ix. *Pipe lines.*—If unburied, destroy junctions, bends, etc. For wholesale destruction fire a charge at alternate joints. If buried, run off the water and fire charges inside them, or dig up and smash them by hand.

x. *Guns.* *See* Sec. **114,** 4.

CHAPTER XXIV

LAND MINES AND TRAPS

118. Types of mines and traps

1. *Land mines* are explosive charges laid in the ground with the object of delaying the advance of an enemy, by impairing his morale, destroying his personnel and transport, and interrupting his communications after the evacuated ground had fallen into his hands.

The quantity of explosive used will depend upon the purpose for which the land mine is laid and may vary from a few pounds to several hundreds. High explosive shells and trench mortar bombs may often be suitably used for the charge in place of bulk high explosive.

Land mines may be divided into three classes according to the method by which they are set in operation.

i. Contact.
ii. Observation.
iii. Delay action.

2. *Contact mines.*—These normally consist of a shell or of a small charge of explosive buried a few inches below the surface of the ground and contained in a specially designed box, fitted in each case with some form of contact firing arrangement. The latter is so constructed that pressure on the surface of the ground caused by troops or vehicles passing over it, sets it in operation, and fires the charge. This firing arrangement in most forms functions by percussion or friction, the release of a striker firing a percussion cap (just as a cartridge is fired in a rifle) or igniting friction composition. In some types, however, it may operate electrically, the pressure on the surface closing a circuit and thus firing the charge.

Two forms of anti-tank mine have been adopted for use in the service.

i. The contact anti-tank mine for road blocks, temporary minefields, etc.
ii. The electro-pneumatic mine for less temporary protection of headquarters, railheads, aerodromes, etc.

3. *The contact anti-tank mine.*—The details of construction are shown on Plate **163.**

i. *Preparation.*—The mine is supplied to the field units that hold them, with the striker assembly separate and the detonator in separate containers. The mine has first to be armed by screwing the striker unit into the hole in the top of the mine. It is safe in this condition.

To render the mine active the detonator has to be inserted into the hole in the side. This is done on the site where the mines are to be laid. They should never be transported with the detonators inserted.

ii. *Laying.*—The mines should not be completely buried as it may be possible for the track of a tank to bridge them from the solid ground on either side. Mines laid in wet sites cannot be trusted to remain effective for long periods.

If friendly transport is required to pass over them the detonators must be removed and the mines themselves taken up to prevent them from becoming damaged.

iii. *Sensitivity.*—The mine will fire under the minimum pressure exerted by the track of a tank or a lorry wheel. It cannot be considered safe under horses and a man jumping on it may fire it. Care in handling is essential.

iv. *Employment.*—In mobile warfare the supply will seldom permit of mining in large areas and they must be used in conjunction with natural obstacles and anti-tank guns.

They will be chiefly used for the protection of roads and defiles; they must be covered by fire so that the enemy cannot remove them.

v. In *planning the lay-out of a road block* two points should be borne in mind.

(*a*) The charge in the mine is sufficient to break the track of the tank and so anchor it, but the crew will probably be uninjured and can, therefore, fight their vehicle until it is knocked out by some other means.

(*b*) The normal procedure on discovering a block will be to work round it, destroy the defending troops and then remove the block.

To meet these contingencies the block should be sited so that it is come upon unexpectedly, at a place where deviation to a flank is awkward and where the likely places for such deviation cannot be foreseen, and the protecting troops should be so located that they are not exposed to direct fire from the anchored tank or from others in rear. Examples of road block lay-outs are given in Plate **164.**

It is, as a rule, difficult to conceal mines in the surface of a metalled road and they may be placed with advantage on the side of the road where some obstacle, such as a crater, forces traffic to make a deviation.

vi. Table 18 show suitable lay-outs for different purposes. (*See also* Plate **165.**)

TABLE 18.—SPACING OF ANTI-TANK MINES

Spacing (1)	Distance C. to C. of mines (2)	Distance between rows (3)	No. of rows (4)	Normal application (5)
Close ...	1 yard.	1 yard.	2 or more.	Road blocks.
Intermediate	2 yards.	5 yards.	2 or more.	Closing more extensive gaps or blocking movement to a flank. *E.g.* deviation from a road to avoid obstacle ahead.
Open ...	10 yards.	10 yards.	Belt of 10 rows. 100 yds. depth.	For an extended minefield.

vii. *Dummy mines* can be used to increase the apparent size of a minefield and for purposes of deception in areas that are not mined. They consist of an empty shell similar in appearance to the cover of an actual mine.

4. *The electro-pneumatic mine.*—The construction of the mine is shown on Plate **163.** This mine is experimental.

A larger charge of explosive than in the former case is buried in the ground and operated by a tentacle of rubber hose 9 ft. long on or just under the surface. The mine produces sufficient effect over the area covered by the tenacle and vehicles need not pass directly over it. A vehicle crossing the tentacle causes a small flow of air to depress the diaphragm in the mine thus completing the circuit between the battery and the No. 13 detonator and firing the mine.

The battery is the ordinary service battery and the container has a switch on the outside. With the switch off the mine is safe.

As a whole assembly is waterproof the mine may be left in the ground for a long period, and will not be damaged by traffic, though the tentacle will get worn in time.

Some improvised types of contact mines are described in Military Engineering, Vol. IV.

5. *Observation mines* are land mines which can be fired

be electricity from a distance when the enemy is seen to pass over them. They may be laid in front of a defended position in ground over which the enemy is likely to advance or mass for attack. Their use, however, as compared with contact mines is rather limited.

6. *Fougasses* may be used as contact or observation mines, usually the latter. A lifting explosive must be used. Fougasses are constructed as shown in Plate **163.**

A charge of 80 lb. of gunpowder will throw 5 tons of bricks or stones over an area 80 yards long by 120 yards wide.

Natural concealment should be used when possible. They are seldom of use against a civilized enemy.

7. *Delay-action mines* are operated by delay-action fuzes (usually containing a steel wire dissolving in corrosive liquid), which enable the explosion to occur at any time desired after laying the charge. Full details are given in Military Engineering, Vol. IV.

Delay-action mines will, as a rule, consist of charges of several hundred pounds laid at depths suitable to form large craters. They are specially suitable for laying in the permanent way of railway lines, bridge abutments, etc., with a view to causing intermittent interruption of road and rail communications after the damage effected by ordinary demolitions before the retreat has been repaired by the enemy. They may also be laid with success in billets, dug-outs, etc., which the enemy is likely to occupy, and in abandoned shell dumps. In the latter case difficulty of detection may be increased by the container of the delay-action fuze being constructed to resemble an ordinary shell fuze.

8. *Traps.*—Improvised contact mines and charges, placed with the object of making the occupation of dug-outs, buildings, etc., dangerous, when abandoned to the enemy are commonly known as " traps." They are not, as a rule, very destructive to personnel, but the atmosphere of uncertainty they produce has a considerable moral effect on advancing troops and may deter them from using much valuable shelter.

In principle their method of working is similar to land contact mines. The design of traps must be adapted to suit the local features of each particular case, and in general the more varied their form the more difficult will be their detection. There is ample scope for ingenuity and cunning in constructing these devices.

The following are a few typical instances of traps that may be laid :—

A loosened board so arranged that a charge is fired when the board is stepped on. An attractive souvenir or trinket so attached to a concealed charge that it fires the latter on being moved. A charge placed in a chimney so that an explosion occurs as soon as a fire is lighted. Charges may be so made up that they are fired on the following actions : the opening of a door, window, cupboard, or drawer ; switching on electric light, pulling the plug of a water-closet, cutting or tripping over a wire.

9. *General remarks.*—The making and laying of all land mines and traps is a dangerous operation, and should be carried out by engineers or others specially trained in the work. Wherever they are to be used on an extensive scale a considered scheme is essential ; careful records should be kept of the position and nature of all mines and traps laid.

In order to deceive the enemy and encourage him to be careless, false indications of mines and traps can be left in likely places. This was done with considerable success in the Great War.

119. The detection of land mines and traps

1. *General reconnaissance in search of mines and traps.*—Mines and traps laid by a skilful enemy are most difficult to detect, and their successful action can only be circumvented by a thorough and conscientious search. During an advance the country must be systematically examined whenever the enemy is suspected of having employed these devices. Specially trained parties of engineers, acting in close co-operation with the infantry, should be used for this purpose. They should be equipped with probing bars, electric torches and wire cutters. Land mines or traps found by troops having no expert knowledge should be thoroughly drenched with water, fenced off, or clearly marked, and then left to be dealt with by trained personnel.

The troops should be instructed in the dangers of mines and traps, and forbidden to enter dug-outs and buildings until the parties of engineers have reported them safe.

In the case of bridges, it will often be advantageous to attach small parties of engineers to the infantry, to try to prevent the enemy pioneers from completing their demolitions.

Reconnaissance parties should be divided into three groups, as follows :—

i. Small detachments, which should include one officer, to keep close up to the infantry and mark all suspicious points with distinguishing signs.

ii. Parties carrying out detailed examination of the points specially marked, and all other places so far as time permits.

iii. Digging squads to work on sites marked by the second party as demanding more thorough investigation at once.

Mines and traps can often be rendered safe very quickly, but as little time as possible should be wasted by the first two parties in actual removal of charges; they should be responsible more particularly for their detection. If charges are not removed, the site must be plainly marked, and the third party instructed to remove them later, otherwise false alarms will subsequently arise.

It will usually be very difficult to carry out thorough investigation sufficiently rapidly to keep up with the advancing infantry. Advantage should, therefore, be taken of any delay in the advance to re-search the area thoroughly—in fact, no area can be considered safe until it has been gone over three or four times.

2. *General remarks.*—The tools to be carried by the respective parties given under (i) are best left to the decision of the unit commander, as the work varies very greatly according to the area.

Probing bars, chalk, and light cord, for attaching to suspicious objects and pulling them from a distance, are very useful.

Electric torches and wire cutters are essential, and every man in the first and second parties must have them.

Prismatic compasses are often of value for detecting shells hidden behind the timber of dug-outs.

Dip needles have also on occasion been of value in detecting shells hidden in the floor or concealed in the roof, and for picking up land and anti-tank mines where these consist of shells or metal boxes.

Detailed reports of the area examined must be sent in by reconnoitring officers.

All places that have been examined and which are not likely to contain delay action mines may be marked "SAFE" (*with the date and number of the unit*), after the first or second examination, according to their nature and degree of importance. It is not, however, possible to *guarantee* the safety of an area or length of railway from delay action mines, and commanders, railway authorities and others must be made to understand this quite clearly.

3. *In searching* suspected localities, the following points should be borne in mind:—

RAILWAYS

i. *Types.*—Almost invariably delay-action.

ii. *Probable sites.*—

(*a*) At all places where the maximum interruption of traffic would be caused, viz.: points, crossing, switches, stations, embankments, culverts and bridges.

(*b*) In the 6-ft. way in double tracks, and between the rails in single.

(*c*) At points 50 to 70 ft. on either side of a bridge, particularly at sites suitable for the abutment of a new bridge. Usual depth of mines, 5 ft.; sometimes up to 15 ft.

iii. *Signs to look for.*—

(*a*) Disturbed ground or small subsidences, especially after rainy weather. A ½-in. iron bar for probing purposes is useful in this connection.

(*b*) Spoil, explosive wrappings, shell baskets, boxes, sawdust, nosecaps and lifting rings.

(*c*) Footprints in a soil foreign to the surface of the ground, *e.g.* chalk marks, where no chalk exists on the surface.

(*d*) Traces of camouflage, withered branches, etc., indicating hidden work in the neighbourhood.

(*e*) Breaks in the continuity of weeds and grease or other marks in the permanent way.

(*f*) Pegs or other marks placed in the ground, without an obvious reason.

iv. *Special points of importance.*—

(*a*) Likely sites must be searched repeatedly, particularly after rain.

(*b*) Railways should be traversed in both directions by search parties.

(*c*) Shallow pits must be probed for charges concealed below the bottom.

(*d*) All ground in the neighbourhood of pits must be searched. In general, anything indicating recent marks must be carefully examined before being considered safe.

(*e*) An open pit, ready for the apparent placing of a mine, should be treated with suspicion since it may have been left and the spoil from it used to conceal a real mine close by.

(*f*) All buildings close to a bridge, level crossings, etc., must be carefully searched: as a gallery from a cellar may lead to a mine in the vicinity.

ROADS

v. *Types.*—Generally delay-action; sometimes land and tank mines.

vi. *Probable sites.*—

(*a*) Important cross-roads.

(*b*) Bridges and culverts.

(*c*) The lips of craters, and any belt of obstruction necessitating a deviation of traffic.

(*d*) Ruins bordering a road.

vii. *Signs to look for.*—

(*a*) Similar to those previously described.

(*b*) Disturbed cobble-stones.

(*c*) Debris heaps and craters on the side of the road, concealing a gallery entrance.

(*d*) Irregular traffic tracks made with no apparent reason.

viii. *Special points of importance.*

As in sub-para. iv, above.

CANALS

ix. *Probable sites.*—At positions where the maximum damage from inundation would result.

x. *Points to look for.*—

(*a*) All ordinary signs indicating work, and the presence of explosives.

(*b*) Leakage of water through the bank, indicating a weakening of the original structure.

(*c*) Careful examination of buildings near locks, sluices, bridges, etc.

(*d*) Careful examination of all siphons.

DUG-OUTS

xi. *Types of traps.*—

(*a*) Obstruction to entrance, loose steps, trip wires, false boards, souvenirs, etc.

(*b*) Delay-action mines, concealed beneath piles of rubbish and explosives, indicating a hurried retirement.

(*c*) Gas shells either exploded before evacuation or used in conjunction with a shell containing a delayed action fuze.

xii. *General.*—The types of traps that may be met with are innumerable, and their successful action can only be circumvented by a thorough and conscientious search. The existence of mines behind the casing of a dug-out can often be detected by a half effaced chalk or similar mark. This is due to the fact that an advance party often marks the best position for mines, which are laid by a working party following it.

4. *Intelligence.*—In advancing through country occupied by friendly inhabitants, arrangements should be made in advance for all reports from civilians regarding enemy activity in respect of mines and traps to be sent at once to the commanding officer of the nearest unit detailed for reconnaissance work. Any information of value should be sent to the reconnaissance parties as soon as possible.

Prisoners—particularly pioneers—able to give any information should be examined at the first opportunity in the presence of a reconnaissance officer. Much valuable information will often be obtained if this is carried out before prisoners are evacuated, and formations should be asked beforehand to co-operate in this respect. In cases of prolonged retreats, it may be possible to discover certain general characteristics of the methods used by particular enemy formations.

Information as to preparatory work done by the enemy can often be obtained from aeroplane photographs taken before the advance begins.

120. Removal

1. *Delay-action mines.—Mines at important sites must be removed at once.* No attempt should ever be made to unscrew the gaine from the fuze, and the fuze itself should be handled as little as possible. All fuzes should be destroyed immediately, and, if possible, the whole of the charge as well as it may contain more than one delay-action fuze.

In the case of mines on railways that it is not intended to use, explosion may be resorted to instead of removal, by firing a charge of about 10 lb. over the suspected site. The risk involved in removing a delay-action mine is considerable, as the jarring may cause the wire, if nearly eaten through, to snap.

While all mines that may hold up the advance must be removed, no lives should be risked unnecessarily in work that has no direct value. If suspected mines are not removed, the site must be plainly marked " DANGEROUS " and fenced off.

2. *Ammunition dumps.*—The fuzes of all shells should be removed, if time permits.

The actual removal of the shells is usually effected by salvage at a later date, but if lying near important roads or sites of camps, they should be removed to a safe distance.

3. *Land mines and anti-tank mines.*—These can usually be rendered harmless very quickly by cutting the fuze and withdrawing the detonators, or, in the case of shells or trench mortar bombs, removing the mushroom head of the fuze. If on roads, the mines themselves should be taken out before the road is reported clear.

4. *Mines fired electrically from a distance.*—In these cases it is sufficient to cut the wire, and remove the explosive as time permits. The same applies to *demolition charges*, unless so sited that they are liable to be exploded by shell fire and cause interruption to communications, in which case they must be removed.

5. *General.*—Explosives, if not actually taken away, should be stacked and plainly marked "EXPLOSIVE: DANGEROUS," and the area wired off. In many cases it will be found desirable to destroy the explosives near the site. This may be effected by laying them out in long lines and burning them. The direction of the wind must be such as to carry the fumes away from any troops. Burning may be assisted by mixing with the propellant charges used for guns.

Explosives should never be thrown into ponds or down wells.

PART VI—ACCOMMODATION AND WATER SUPPLY

CHAPTER XXV

ACCOMMODATION, SANITATION AND COOKING ARRANGEMENTS

121. Accommodation

1. *The types of accommodation* provided for an army in the field are: billets, bivouacs, temporary camps, semi-permanent camps, standing camps.

Standing camps and all types of hutting are dealt with in Military Engineering, Vol. VII; the other types are dealt with in the following sections.

122. Billets

1. *Temporary billets.*—The most useful improvements, other than purely defensive measures, are those that tend to improve the sanitary conditions and the comfort of the troops, such as arrangements for drying clothes, heating and erection of baths.

2. *Standing billets.*—These may be expected to last for some months. Improvements will include: Erection of bunks in barns, etc. (Plate **166**), sanitary appliances, cook-houses, heating arrangements in winter, baths, drying rooms, oiled silk windows, electric lighting if possible, or hooks for hurricane lamps.

123. Bivouacs

1. A bivouac is a camp without tents or huts, where the troops have to make their own shelter. The area required may be calculated from the basic figures given in Table 19, p. 304.

2. A simple shelter can be formed by driving into the ground two sticks with forked ends and then laying another stick across them as a ridge pole. Branches are then laid at a slope of 45 degrees (1/1), with their thick ends resting on

TABLE 19

Class (1)	Area (2)	Examples (3)
Infantry	15 sq. yds. a man.	
Other dismounted units	25 sq. yds. a man.	Field Company R.E. (horsed). Field Ambulance. Provost Company.
Mounted units ...	50 sq. yds. an animal.	Cavalry Regiment. Field Brigade R.A. (horsed). Light Brigade R.A.
Mechanized units ...	120 sq. yds. a vehicle.	Field Company R.E. (mechanized). Field Park Company. R. A. Units (mechanized). Ordnance Mobile Workshop. Tank Battalion.

the pole and their other ends on the ground, smaller branches and grass being placed on the larger branches to make a thicker roof.

Instead of branches, hurdles can be used, or a tent can be made with blankets or waterproof sheets.

To keep out the rain the blankets or waterproof sheets must overlap one another by at least 6 in. where they are joined on the ridge pole.

3. For drainage in bivouacs, *see* Sec. **124**, 3, and Plate **167**.

124. Camps

1. Temporary camps are little more than tented bivouacs and will not be occupied for more than a few days.

Semi-permanent camps are camps of tents or huts which will be occupied for periods of a week or more and will require a considerable amount of accessories such as cookhouse, horse standings, etc.

The period of occupation proposed will decide the amount of work that should be undertaken for the improvement of the camp.

2. *Choice of temporary and semi-permanent camp sites.*—The following rules must be observed in deciding on the lay-out of the site :—

i. *Water supply.*—This must be kept pure. The lay-out of the camp should allow for a simple and economic run of piping.

ii. *Latrines and incinerators.*—These should be situated so that :—

(*a*) They are to leeward of the camp.

(*b*) They are as far as possible from the cookhouses and water supply.

(*c*) No foul matter can drain into the water supply.

(*d*) They are easily accessible from the men's lines.

iii. *Cookhouses and dining-rooms.*—Cookhouses should be close to the water supply and convenient to messing tents or huts.

Centralization of cooking arrangements is economical and convenient ; it is, therefore, better to have one large cookhouse then several small ones.

Drains must be dug, if necessary, to prevent dirty water from fouling the water supply.

Separate dining-rooms should be provided. If it can be avoided men should not be permitted to have meals in sleeping tents, as this practice is detrimental to health and to the cleanliness of the camp.

iv. *Horse lines.* These should be so sited that :—

(*a*) They are to leeward of the camp.

(*b*) Their approaches do not lie through the centre of the camp.

v. *Boundaries.*—Should be definite and there should be a marked entrance, to avoid men and animals entering at any point of the perimeter.

vi. *Drainage.*—Should be provided under three headings :—

(*a*) *Catch-water drains.*—To prevent rainwater entering the camp site from higher ground.

(*b*) *General drainage*, of camp area. The whole area should be provided with a series of main drains into which fall the subsidiary drains from tents, standings, cookhouses, etc.

The best form of surface drain is a shallow cobble drain which is not liable to damage by wheeled traffic.

Brick drains will not bear wheeled traffic. In such cases, culverts to roads are required, or an open section of concrete or cobbles.

The capacity of surface drains is governed by the fall. The minimum fall may be taken as that given to sewers, *i.e.*, a 6-in. semi-circular or V drain should be given a fall of not less than 1 in 60, and a 10-in. one not less than 1 in 100.

A 4-in. drain is the smallest one used in practice, and at a minimum slope of 1 in 40 will dispose of 140 gals. of sullage water a minute.

(*c*) *Subsidiary drains.*—All roads, paths, tent standings and ablution places require separate drains.

vii. *Parade grounds.*—The most level portion of the area should normally be set aside as a parade ground. Minimum dimensions 50 yards by 100 yards for a battalion, battery or cavalry regiment.

3. *Tents.*—

i. Men sleeping on the ground in tents and bivouacs suffer discomfort from two main causes :—

(*a*) Rainwater.

(*b*) Draughts.

ii. *Disposal of rainwater.*—Plate **167** shows the right and the wrong way of disposing of rainwater from tents and bivouacs. By the right method the water is conducted from the roof to the ground and is led away in the drain to the lower ground. By the wrong method the rain running down the sides of the tent or bivouac soaks the earth which is placed on the canvas, and the water leaks through the canvas and over the floor.

iii. *Draughts.*—The proper arrangements for the disposal of rainwater also prevents draughts along the level of the floor. Therefore the sides of the tent should be well pegged down and the edges of the waterproof sheets or blankets, in bivouacs, should reach the ground.

iv. In very hot weather the tent can be made much cooler by putting over it grass thatching, local matting, etc., supported by a light wooden or bamboo frame.

4. *Horse lines.*—Standings should give each horse a space of 5 ft. wide and 12 ft. long. A gangway 15 ft. wide should be left between lines. Standings must be well-drained, *i.e.* an ample ditch should be dug along the back of the standings, and a catchwater drain dug round and above the whole horse lines area.

Standings must be of the hardest material available, concrete or brick are the best ; if these are not obtainable corduroy of logs, gravel, or rammed broken brick may be used.

If a hard surface cannot be obtained, a site must be chosen that permits of the lines being frequently moved.

5. *Protection from splinters.*—

i. *Tents.*—To protect men sleeping in tents from splinters of shells and bombs, a wall 2 ft. high and about 2 ft. thick, made of sandbags or earth, if sandbags are not available, can be built round the tent. This wall must be clear of the drains mentioned in para. 3, above. If drainage permits, protection may also be obtained by sinking the floor-level.

ii. *Huts.*—Splinter-proof walls of earth, shingle, etc., must be constructed round each hut as a protection against splinters from shells or bombs from aeroplanes. To economize material and labour and to increase the protection afforded, the floors of all huts should be close to the ground level, or in dry sites, below ground level ; on sloping ground the site of each hut should be levelled by cutting into the slope of the hill.

iii. *Horse lines.*—Horse lines are particularly vulnerable to attack from aeroplanes using bombs and, if such attack is likely, earth or mud walls (about 4½ ft. high) should be built round the stables, clear of the drains, to stop splinters.

In long stables traverses should be made to divide the space up into compartments containing not more than twenty horses each. If serious enemy air activity is likely, animals should be stabled in units of not more than fifty ; units separated by intervals of 60 ft.

Concealment from the air and partial protection may sometimes be obtained by placing horse lines under trees.

125. Sanitation

1. *Latrines.*—

i. ***Shallow trench latrines*** (*see* **Army Manual of Hygiene and Sanitation, 1934, Fig. 23**). **The simplest form of latrine for temporary use consists of shallow trenches dug side by side, 2 ft. apart, 3 ft. long, 2 ft. deep, and 1 ft. broad.**

The turf and earth should be placed at the head of the trench.

This pattern latrine is only suitable for very temporary use, such as midday halts on the march, or for a bivouac or camp lasting not more than two days. They foul a large area of ground ; they should not, therefore, be used when the site is likely to be in constant use as a bivouacking area.

The following points should be noted in connection with shallow latrines :—

(*a*) Scale of provision should be five for the first 100 men and three for every additional hundred.

(*b*) Separate latrines are required for officers, warrant officers and serjeants and men. These should be clearly marked as such.

(*c*) They must be filled in daily.

(*d*) A new series, in front of those of the previous day, should be dug for subsequent days.

(*e*) **A shovel must be provided, so that each man may cover his own faeces at once. Policing is necessary to ensure that this is properly done.**

(*f*) Screens and overhead cover should be provided.
(*g*) Sites should be clearly marked (*e.g.*, with an "L" in stone) on vacation.

ii. *Deep trench latrines* (Plate **168**) are dug, providing the soil is suitable, for all camps likely to be in continuous use for more than a few days. They should also be provided for all camp sites likely to be used at frequent intervals—*e.g.* on a L. of C. when pail latrines are not installed.

They should not be dug in chalk soil, where there is a danger of contaminating the water supply.

Points to note are :—

(*a*) Scale of provision is normally five seats for the first 100 men and three for each additional hundred. Additional seats, partitioned off, should be provided for officers and N.C.Os.
(*b*) Flyproof seats, with self-closing lids, are essential.
(*c*) All woodwork must be in good condition, cracks caulked.
(*d*) Revetment is necessary in sandy soil.

iii. *Bucket latrines* (Plate **169**) combined with incinerators for burning excreta, should be provided in all standing and hutted camps.

Points to note are :—

(*a*) Seats should fit closely on the pails and seat covers must be self-closing.
(*b*) Scale of provision is five seats for every 100 men. Additional seats, partitioned off, should be provided for officers and N.C.Os.

Otway's pit for disposal of the contents of latrine buckets when burning is not possible: this is described in Army Manual of Hygiene and Sanitation.

2. *Urinals.*—An efficient form of urinal is an open hole in the ground filled in with bricks or brushwood. This is only good enough for bivouacs where troops remain only for a short time, and should be sited near the latrines.

Buckets or tins must be provided for use at night otherwise some men will foul the ground near the camp rather than take the trouble to go to the proper place.

Night arrangements should be close to the men and lamps should be provided.

Trough urinals (Plate **170,** Figs. 1, 2 and 3) from which the urine passes by a pipe covered with a grid to a soak pit are the most useful type for a semi-permanent camp, where water carriage is not provided. A soak pit 4 ft. by 4 ft. by 4 ft. will deal with urine for half a battalion of infantry in ordinary porous soil. One trough 8 ft. long is required for every 100 men. Fig. 4 shows a type of funnel latrine suitable for placing outside canteens and messes or at end of tent lines for night use. Other types are shown in the Manual of Hygiene and Sanitation, 1934, Fig. 28.

3. *Incinerators and disposal of refuse.*—

i. *All refuse* should, if possible, be burned ; what cannot be burned should be removed and buried.

Many types of incinerators have been devised but they all belong to one of three groups, namely, open, closed, or semi-closed. Closed incinerators are the most efficient and should be adopted in standing camps. An open turf incinerator is shown on Plate **171.** An oil drum with the bottom knocked out of it supported on a grid of iron bars resting on stones or bricks makes a good temporary incinerator. Spaces must be left below the grid to form air holes and for raking out ashes.

A good portable incinerator made from corrugated iron is shown on Plate **172**. Other types of incinerators, closed and semi-closed, of a more permanent nature are illustrated in the Army Manual of Hygiene and Sanitation, and in Military Engineering, Vol. VII.

ii. *Disposal of refuse by burial* is rarely satisfactory, but if it cannot be burnt it should be buried deeply in a pit, care being taken that fresh additions are covered immediately and the pit, when full, covered with rammed earth mixed with heavy oil.

In camps numerous small receptacles such as sandbags, tins, etc., should be provided for paper and similar refuse.

iii. *Disposal of manure.*—Manure forms a favourite breeding ground for flies and should be burned where possible. Other methods of disposal are tight packing, spreading, or removal by contractors.

The single trench manure incinerator consists of a trench 9 ft. long, 1½ ft. wide and 6 in. deep at one end and 1 ft. 6 in. deep at the other end the mouth of which is splayed out. The trench is covered with expanded metal measuring 9 ft. by 3 ft. With the help of an oil and crater flash fire a trench of this size will burn the litter from fifty horses in a day.

The cross-trench incinerator is similar to the above, but consists of two trenches crossing at right angles. The expanded metal covering the centre portion must be supported. This is illustrated in plate **171.** Basket incinerators may be made from baling wire or hoop iron woven into flat sheets which are then wired together to form a rectangular basket. This is supported on the four corners. In dry climates where the manure can be dried the mesh should not be more than 1-in. : elsewhere a 2-in. mesh will suffice.

In tropical climates manure can be spread over the ground and dried in the sun.

Tight packing is described in the Army Manual of Hygiene and Sanitation.

iv. *Disposal of dead animals.*—If incinerators for burning dead animals have not been constructed, the animals should be skinned, cut open and buried, the place being clearly marked as "foul ground."

4. *Drainage, soak pits, and grease traps.*—

i. *Dirty water* from washing places and from cleaning cooking pots, etc., is got rid of in two ways.

(*a*) By draining it away to low ground outside the camp. In malarial countries, drains may have to extend some distance to avoid creating mosquito breeding places close to the camp.

(*b*) By making it run into pits dug in porous ground.

In either case grease and soap must first be removed by means of a grease trap.

ii. The first method is satisfactory for rain water or for water from a big washing place. A series of connecting channels 1 ft. wide and 1 ft. deep are dug in a herring-bone pattern so that the different sections can be used alternately. The water evaporates and also soaks into the soil. The channels must be kept clean.

iii. The second method is often used where the quantity of water to be dealt with is small and ground is sandy.

A pit is dug in the ground, about 4 ft. square and from 4 to 6 ft. deep.

This is partly filled with large stones, bricks or cut bushes. A tube made from tins or corrugated iron is put down the middle and the pit is then filled up to within 6 in. of the top with stones or other material. Then to prevent flies, sacking is spread over the pit and 6 in. of sand placed on this.

It is wise to have reserve pits available and in clay soil that is essential.

iv. *Grease traps.*—If hot water containing fat in solution is passed into a large volume of cold water, the fat solidifies and floats to the surface and can be removed.

A type of grease trap is shown in Plate **173,** Fig. 4. In this the water has to run under and over the baffles in the trap. As the grease separates out it is held up by the baffles and can be removed and burned as required.

A simple type of strainer trap, suitable for bivouacs or camps of short duration is shown in Plate **173,** Fig. 1. A more elaborate type suitable for temporary camps is shown in Plate **173,** Fig. 2.

In each case the straining material, grass, bracken or similar material must be changed daily and burnt.

Soap.—Soap can be removed by the same type of trap provided the soapy water is doped with alum, bleach, or lime as it enters the first compartment.

5. *Prevention of mosquitoes.*—To prevent mosquitoes breed ing, camps should be properly drained and all pools of water should be either drained or covered with a thin layer of oil.

The smallest quantity of water is sufficient for mosquitoes to breed in, empty tins, hoof prints and similar small possible receptacles for water should therefore not be overlooked.

6. *Drying of clothes.*—For drying clothes a simple framework of wood and cord or wire may be rigged up either within a large tent or under some shelter and one or more braziers, improvised from old buckets or tins and burning coke or charcoal, placed inside. Efficient ventilation is a necessity.

7. *Conservancy and food precautions in trenches that are occupied for extended periods.*—The burning of refuse and faecal material is generally impracticable and some system of burial has to be adopted. Where the water level is suitable fly-proof pit latrines placed in T saps can be used with advantage. Where the water level is high or there is a risk of flooding, receptacle latrines with fly-proof covers must be used. The contents of these receptacles must not be thrown into shell holes, but buried in pits well away from any occupied trench or dug-out. The site for refuse pits may be in an abandoned trench. Two pits are dug about 4-ft. deep, one for liquid and one for solid refuse. After the refuse is deposited in the pits it is covered with earth, a sacking cover being used if and where possible.

Food safes, which must be rat-proof, may be improvised from tins let into the walls of dug-outs.

Food can be kept warm for several hours if placed in a "hot box." This is a double box (Army Manual of Hygiene and Sanitation, 1934, Fig. 12), the space between the inner and outer casings being filled with hay, chopped straw, paper, wool, etc.

126. Cooking arrangements

1. *In the open.*—A simple arrangement for cooking in the field for any party over twenty, if halts are not of long duration, is to place a proportion of the kettles on the ground in two parallel rows 9 in. apart, handles outwards; block the leeward end of the trench so formed with another kettle; lay the fire between the kettles and place one or two rows of

kettles on those already in position. Mess tins can be arranged similarly, but not more than eight should be used together.

2. *In trenches.*—Another method is to dig or raise a narrow sloping trench for the fire on which the kettles are placed. The interstices round the base of the kettles are then filled up with clay so that the fire, fed from the windward end, may draw right through. A chimney may be built at the other end to increase the draught.

3. More elaborate field kitchens can be made of brick. Some types of field ovens are shown on Plates **175** to **178**.

4. Weatherproof cover should be provided for cooks and for the storage of rations. A simple timber framework with end, sides and roof of corrugated iron will suffice. The roof should have a good fall to carry off rain.

5. For storing rations, a fly-proof safe is essential in warm weather. A safe of light timber framing provided with hooks from which to hang meat, and covered with fly-proof gauze can be made to any size required. A portable pattern is shown on Plate **174**.

6. For washing cooking pots a good table can be made from a sheet of corrugated iron supported on bricks or on light wooden trestles, so that one end is slightly higher than the other, and the sides slightly higher than the middle. The table should be arranged to drain into a grease trap.

CHAPTER XXVI

WATER SUPPLY

127. General

1. *Responsibility.*—The engineers are responsible for ascertaining sources of supply and for all the works connected with the raising and delivering of the water to agreed points, including plant required for purification purposes.

The medical service is responsible for advice as to the suitability of water for human consumption and as to methods of purification to be adopted.

Units are responsible for all duties in connection with water they have taken over, for the provision of labour required for operating hand pumps at the water points and for the erection of water containers that form part of their own equipment.

2. The work consists of :—

i. Development of the source, which involves :—
   (*a*) Reconnaissance.
   (*b*) Constructional work, well-digging, etc.
   (*c*) Means of raising water.
ii. Purification.
iii. Storage, which compensates for fluctuations in supply and demand. This may be necessary at any point in the system.
iv. Distribution, or the means by which the water is conveyed to the consumer.

3. Normally army troops companies, field companies, and field squadrons will carry out water supply work. Their equipment for this purpose is given in Table 20.

128. Water reconnaissance

1. *Sources of supply.*—The sources of supply most commonly met with, arranged in decreasing order of probable purity, are :—

Artesian wells, deep wells, springs, rain water, large lakes (centre of), rivers (mid-stream), small streams, large lakes (near bank), shallow wells, rivers (near bank), and ponds.

TABLE 20.—WATER SUPPLY EQUIPMENT OF UNITS

Equipment (1)	Field squadron (2)	Field company (3)	Field park company (4)	A.T. company (5)	Remarks (6)
Water carts (*a*)	—	1	—	—	(*a*) Also 2 for each battalion. For other units, 1 for each squadron, battery or company. (*b*) Establishment on same scale as water carts, for mechanized units. (*c*) Combined with cooker.
Water tank trailers (*b*)	1 (*c*)	—	1	1	
Troughs, waterproof, 350-gal. ...	4	6	4	6	
Tanks, waterproof, 1,500-gal. ...	1	1	5	3	
Pumps L. and F.	4	6	4	6	
Pumping sets, centrifugal No. 1 (Rees-Roturbo type).	—	1	2	1	
Water elevators, power (Aquatole type).	—	1	3	1	
Hose, canvas, 2 in. by 30 ft. ...	8	12	—	18	
Hose, prepared canvas, 1¾ in. by 12 ft.	24	16	—	36	

Other standard stores for mobile purposes : Norton tube well.

Piped supplies may also be met with and, if they have not been tampered with, are likely to provide a pure supply.

2. *Reconnaissance* for water is an important engineer duty. The information required is as follows :—

i. Nature of source.

ii. Quantity available an hour, and any factors that may affect this.

iii. Quality, *i.e.* purity of water. This is determined by Horrocks Test, details of which are given in the Army Manual of Sanitation and Hygiene and in every regimental water cart or trailer.

iv. Nature of surroundings with a view to protection of the source from fouling.

Reconnaissance will normally be carried out by an officer or special water-supply personnel, but every N.C.O. should be capable of testing the yield of a source of supply.

3. *Measurement of yield*—

i. An approximate estimate of the average yield of a spring or stream may be made as follows :—

Select a straight length of 15 to 20 yards where the channel is fairly uniform and there are no eddies. Measure the breadth and depth at three or four places, and from these obtain the average sectional area (A) of the channel, in sq. ft.

Drop in a chip of wood, find the time in seconds that it takes to travel a known distance in feet (say 30 ft.), and thence obtain the surface velocity (V) of the stream in ft. a second.

Then : $\frac{4}{5}$ V × A = yield in cu. ft. a second
or $\frac{4}{5}$ V × A × 6¼ × 60 = yield in gals. a minute.

In the case of a spring, a measurement point should be selected as near its outflow as possible. Care must be taken that the whole outflow from the spring passes along the measuring channel. When the yield is very small, it is best measured by noting the time taken to fill a vessel of known capacity.

The most accurate method of measuring the flow of any stream is by the use of a weir as described in Military Engineering, Vol. VI.

ii. The most practical method of gauging the yield of a well, if this cannot be obtained from local inhabitants, is to pump the water down to a definite level and take the time of refilling to the former level. Note the apparent yield is not directly proportional to the depth pumped out, *e.g.* the apparent yield is greater if 4 ft. is pumped out than if only 6 in. is pumped out. Each case must be judged on its own merits.

The contents of circular wells for 1 ft. of depth are :—

3-ft. diameter	...	44 gals.
4-ft. diameter	...	78 gals.
5-ft. diameter	...	122 gals.
6-ft. diameter	...	176 gals.

The yield of a borehole can usually only be directly determined by pumping at the maximum possible rate into a receptacle of known volume, or into a *weir box*. (*See* Military Engineering, Vol. VI.)

129. Methods of raising water

1. It is usually necessary both to raise water to the ground level from a well or river and to force it above ground level to storage tanks from which it can be drawn off.

The ordinary suction pump cannot, for physical reasons, raise or lift water more than 28 ft. 18 ft. is a working figure for pumps that are not new. If it is desired therefore to raise water from a well or boring deeper than this and if the pump cannot be placed down the well on a staging, it is necessary to use some type of mechanical elevator main lift pump. Experiments are being made with a flexible drive that may enable a pump to be lowered down a well while the power unit is retained on the surface.

Tables 21 and 22 give details of the pumps that are commonly available in the service.

Notes on the use of these pumps are given in the following paragraphs. Particulars of output, etc., are given in Tables 21 and 22.

2. *Lift and force pump.*—This is the normal unit equipment. It is capable of a combined lift and force of 60 ft., of which not more than 25 ft. can be lift (28 ft. is a maximum with a new pump).

Plate **179** shows a diagram of the pump.

The equipment consists of—

- i. *Pump*, mounted on base with hinged ends. Particulars are given in Table 21.
- ii. *Handle lever.*
- iii. *Armoured suction hose*, in 12-ft. lengths, four.
- iv. *Canvas delivery hose*, in 30-ft. lengths, one.
- v. *Strainer* for attachment to suction house, consisting of a perforated steel drum, fitted with foot valve and dome.

TABLE 21.—HAND PUMPS

Type (1)	Makers' name (2)	Head ft. (3)	Delivery, gals. an hour (4)	Suction lift ft.		Connections (7)	Weight (lb.) (8)	Floor space (9)	Height (10)	Bore (11)	Stroke (12)	Remarks (13)
				max. (5)	normal (6)							
Lift and force.	Service pattern.	12 and under	700 (*a*) 750 (*b*)	20 : 28	15 : 18	2-in.	84 (*c*)	19 in. × 10⅜ in. shut 43 in. × 10⅜ in. open	4 ft. 0 in. (*d*)	4½ in.	12 3/16 in.	(*a*) 2 men working. (*b*) 4 men working. (*c*) with normal length of suction and delivery hose. (*d*) to top of handle.
		20	600 (*a*) 700 (*b*)									
		30	550 (*a*) 650 (*b*)									
		40	500 (*a*) 600 (*b*)									
		50	Nil (*a*) 550 (*b*)									
		60	Nil (*a*) 500 (*b*)									
Suction lift.	Norton tube well.	20 : 28	300	20 : 28	15 : 18	1¼ in.	33	2 ft. 0 in. × 1 ft. 6 in.	1ft. 6 in.	3 in.	6 in.	

TABLE 22.—POWER PUMPS AND ELEVATORS

Type (1)	Makers' name (2)	Head ft. (3)	Delivery, gals. an hour (4)	H.P. and type of usual prime mover (5)	Weight cwt. (6)	Remarks (7)
Centrifugal ...	Pumping set. Centrifugal No. 1 (Rees Roturbo type).	100	3,000	Engine petrol 5 B.H.P. (Watermota 2-stroke) (included in pump set).	265	Overall dimensions 3 ft. 6 in. × 1 ft. 6 in. × 2 ft. 0 in. Delivery valve provided, but no priming pump. Standard service hose.
Chain water elevator.	Water elevator No. 1 power driven (Aquatole type).	Down to 150-ft. depth.	3,000 approx.	Engine petrol 3–5 B.H.P. (Watermota 2-stroke) (belt driven).	Elevator only 10 cwt. (including 250 ft. of chain).	Supplied complete with elevator engine, bedplate and flume fitted for service hose. Chain length varied by multiples of 4 ft. Immersion should not exceed 6 to 7 ft. (Makers' type F1.)
Water elevator	Water elevator (Boulton and Paul type).	Down to 150-ft. depth.	3,000 approx.	No special provision but petrol engine as above is suitable, 3–5 B.H.P.	Elevator only 16 cwt. (including 250 ft. of band).	Band length varied by multiples of 25 ft. Immersion should not exceed 17 ft. (Makers' heavy-duty type No. 1.)

vi. Three adaptors to enable hose of 3¼-in. old Metropolitan Fire Brigade thread to be used with unions threaded 2-in. pipe thread.

vii. Two hose wrenches.

To erect the pump :—

i. Join the necessary lengths of suction and delivery hose respectively. Joints must be tight. Use the wrenches provided. Do not hammer the lugs on the unions, or they will break. Attach the strainer to one end of the suction hose.

ii. Prime the pump by filling with water through one opening, whilst holding a hand over the other. Join the suction hose to the hole marked " S," and the delivery hose to the hole marked " D."

iii. Place the strainer in the water, fastening it to a picket, or placing it in a box, so that it does not lie on the bottom of the pond, stream, etc. Fill the suction hose with water.

iv. Start pumping fairly fast, until the water is flowing freely, after which maintain a rate of about 110 strokes a minute.

The action of the lift and force pump depends on a number of leather valves. If the leather gets dry the pump will not function. Pumps that are not in use must, therefore, be kept full of water. Filling a pump when dismantling should be a matter of routine.

3. *Norton tube wells* (Plates **180** and **181**).

i. Useful in the search for water, and for raising water from pounds and rivers, for filling troughs, etc., and so preventing animals entering the water or pails being dipped therein.

ii. The well consists of a number of iron tubes, 1¼-in. internal diameter, each tube being threaded at both ends. They are joined together by means of barrel-shaped sockets, 2½ in. long, tapped to fit the tubes. *Tongs* are provided for holding the tubes and sockets while screwing them together.

One length of tube has a steel point welded into it, and part of it is perforated, the perforations being covered by a perforated brass sheath which acts as a strainer.

iii. The well is driven into the ground by blows delivered either on a *driving cap* or a *driving clamp*. The cap is used in soft ground ; the clamp in harder ground.

The rim of the cap has two holes into which the ends of the handles of the tongs fit when screwing the cap on the well.

The clamp is in two halves and may be fixed to any part of the tube.

The blow on the cap or clamp is delivered by a *monkey* weighing 84 lb., having a 1¾-in. hole through the centre, so as to slide freely on the tubes, and provided with two ropes. The latter passes over two sheaves at the top of a pulley bar, which is a 4 ft. 6 in. length of well tube with a solid bar welded in and projecting 12 in. at one end and carrying a head with the sheaves at the other end.

iv. *Driving the well.*—

(*a*) Make a hole with a crowbar, and insert well tube about 2 ft.

(*b*) Screw on the clamp, tightening each bolt equally so as not to damage the tube. If the ground is soft, screw on the cap instead.

(*c*) Place the monkey on the cap or clamp, insert the pulley bar in the tube, pass the ropes over the sheaves, and make fast one end of each to the monkey.

(*d*) Two men raise the monkey by pulling on the ropes at the same angle (the nearer the vertical the better). They must stand exactly opposite one another, work together and very steadily so as to prevent the tube from swaying about.

(*e*) If the clamp is being used, see that it does not slip on the tube. Tighten the bolts after the first, third and seventh blows, and after every twelve blows afterwards.

(*f*) When the clamp has been driven down to the ground the pulley men raise the monkey, and take a hitch with the running parts of their ropes round the pulley bar below the monkey. The screws of the clamp are then slackened, and the clamp screwed to the tube again two or three feet from the ground.

(*g*) When the tube has been driven until there is not sufficient drop for the monkey, remove the monkey and pulley bar, and screw on a fresh length of tube. The two tubes *must* butt against one another, otherwise the thread may be injured. Use red lead on the threads before joining to ensure a watertight joint.

(*h*) Resume driving, turning the upper length of the tube after a few blows to tighten the joint.

(*i*) From time to time, and always before screwing on a new length of tube, sound the well by means of a small lead on a line, to ascertain the depth of water (if any), and character of the earth. The rate of driving varies from 12 ft. an hour in chalk to 20 ft. an hour in soft ground.

(*j*) When water is reached, do not drive too far. The water-bearing layer of soil may be quite thin, and over-driving may force the perforated spearhead into an underlying layer containing no available water.

(*k*) When the well has been driven far enough, screw the pump on to the top of the well. Take great care that the joint is airtight. Use red lead. If air can be heard passing through the joint when pumping, remove the pump and remake the joint.

(*l*) Prime the pump by pouring water in the top. Work the pump until the air is exhausted from the tube. Water should follow.

At first water may only come slowly, but by making use of the *tilting* action of the pump, by which means the water in the pump and well is allowed to run down the tube again, so washing mud, etc., from the holes in the bottom tube, the flow will eventually increase. The tilting action is brought into play when the bucket is turned into such a position that, on raising the handle, the screws projecting from the bottom of the bucket press on the projecting lug on the lower (clack) valve. In some soils, however, the bottom of the tube may become silted up, in which case it is necessary to use the cleaning apparatus.

v. *Cleaning apparatus.*—This consists of :—

(*a*) *Cleaning tubes*, with threaded ends and sockets as for the well tubes. One after another is lowered until the lowest one touches the obstruction. Hold carefully, for a dropped tube cannot be recovered without drawing the well.

(*b*) *Funnel* screwed on top of the well.

Attach the pump to the cleaning tubes by means of the reducing socket, pour water down the funnel outside the cleaning tubes. While doing this, hold the cleaning tubes and pump an inch or so above the silt, by means of the clip provided.

As the accumulation is brought up, gradually lower the cleaning tubes, until the bottom of the well is reached. Then remove the cleaning apparatus and connect the pump to the well as described above.

Five men are required for driving the well quickly, two reliefs for the monkey, and one man to hold the well steady and attend to the clamp.

vi. *Drawing the well.*—When no longer required, the well may be drawn :—

(*a*) By turning the well right-handed with the tongs, at the same time lifting upwards.

(*b*) By passing a short chain twice round the tube, close to the ground and taking one end through a large ring on the other end. Next put the end of the chain through a movable *stopper link* which will grip any link desired. Insert a lever into the stopper link, and lever the well up.

(*c*) By placing the monkey upside down on the tube, with the clamp face downwards about a foot above it. Raise the monkey smartly, and so start the well. Lower the clamp as required. Do not attempt this method with the cap, or its threads will be damaged.

4. *Water elevators* :—

i. The essential feature of a water elevator is an endless belt (or chain) carried over a fixed top pulley in the head gear and kept taut by a loose bottom pulley down the well. When power is applied to the shaft at the top the belt (or chain) revolving round the pulleys is drawn through the water at the bottom and, as the ascending side leaves the water, forces of capillary attraction and surface tension result in the water being lifted and held in the cells (or coils) of the belt (or chain). As it passes over the top pulley centrifugal force causes the water to be thrown off the belt.

The apparatus is particularly useful for lifting water from open wells not less than 2 ft. or so in diameter.

ii. *Canvas belt type elevator.*—This is the simplest form and can be quickly improvised. It consists of a canvas or similar belt. A quickly-made belt pump designed for an output of 1,000 to 2,000 gals. an hour is shown on Plate **182**. The belt is mounted on a G.S. wagon, and driven by a 5-h.p. petrol engine.

The following conclusions have been drawn from trials of this pump in wells of varying depths.

The diameter of the belt drum should be 1 ft. 3 in. and have a camber of 1/24. The belt should be 8 in. wide, and weight ·346 lb. a yard.

Slip is best avoided by tacking a strip of canvas 4 in. wide round the middle of the pulley.

Immersion.—The best results are obtained with this pump when the lowest point of the belt is 6 in. from the bottom of the well when the pump is not working.

Depth from ground to water.—As the depth from the ground to the water decreases, the belt has less chance to become steady before reaching the drum: also there is less weight on the drum and more tendency for slip, with consequent belt wear. This is overcome by using two or more belts superimposed.

Generally speaking, the deeper the well the greater the permissible speed. (*See* Military Engineering, Vol. VI, for details.)

A bottom pulley is rarely found to be any advantage in this type.

iii. *Boulton & Paul Elevator.*—This consists of a balata belting to which are riveted open-ended cells of aluminium bronze. Full details are given in Military Engineering, Vol. VI.

iv. *The Aquatole elevator* (Plate **183**) gives very similar results to the Boulton & Paul elevator and has been chosen for field unit equipment. The band consists of an open endless chain of galvanized steel wire coils linked by horizontal pins, made up in 4-ft. lengths. A bottom pulley is provided to keep the belt taut.

To get the maximum efficiency the chain must be run at the correct specified speed. The standard Watermota engine provided gives 400 r.p.m. The chain must also be submerged the correct depth. The lower pulley centre should never be less than 1 ft. submerged, but greater depths of submergence decrease the efficiency.

5. *Rees-Roturbo pumping set* (Plate **184**).—The pump is a two-stage centrifugal, coupled by gearing to a Watermota 2-stroke engine, the whole mounted on a girder bed provided with detachable handles.

To avoid trouble in priming, the following points are important :—

i. Joints on suction side must be properly tight.

ii. A foot valve in good order must be fitted, the ordinary L. and F. pump foot valve is suitable. Particular care must be taken to see that it is watertight.

The set is fitted with a stop valve which should be closed at starting. Both suction inlet and delivery outlet are fitted with gunmetal connectors to fit P Mk. 11 unions. A four-way hose connector and two adapters also form part of the equipment.

6. *Other methods of raising water.*

i. Bucket or water lift (Plate **185**). The horizontal spar is so adjusted that the weight of stone or clay at the shorter end readily lifts the bucket attached to the longer end when full of water. Efficiency may be increased by fitting a foot valve at the bottom of the bucket.

ii. Water bag (Plate **186**) is an Eastern device for raising water from wells or irrigation channels.

iii. Air lift. Can only be used under suitable conditions. Full particulars are given in Military Engineering, Vol. VI.

iv. Siphons. Water can be transferred from one tank to another at a lower level by means of a *siphon*, for which a non-collapsible tube, such as suction hose, is required. All joints must be airtight. When a pump is available, it should be used, as a siphon is sometimes awkward to start, and the rate of flow is usually slow.

To start a siphon working :—

Hold up both ends of the hose at the same level ; fill hose with water ; a man at each end of hose holds his hand over the end. Lower each end into its tank, taking care that no water escapes from the hose. When the upper end is well below water-level, the N.C.O. orders the men to remove their hands, which they must do simultaneously. The lower end of the hose should be turned upwards.

Water will continue to flow until the water level is the same in both tanks.

130. Purification of water

1. On active service all water must be considered as polluted and must be chlorinated for drinking purposes.

2. For field purposes the process of purification is reduced to :—

i. *Clarification*, to remove suspended matter. This is done by filtration or sedimentation. A little alum added to the water assists sedimentation or the settling out of suspended matter.

ii. *Sterilization*, to destroy bacteria. This is done by chlorination.

3. *Methods of purification in the field.*

i. *The regimental water cart* (*capacity* 100 *gals.*) *and water tank trailer* (*capacity* 150 *gals.*).—This is the main apparatus available to all units, and each is a complete pumping, filtration and storage installation.

The maximum lift is 28 ft. (15 to 18 ft. is usual). One hour is required to deal with a fill of untreated water. Thus it takes 12 hours to supply a battalion with one gal. for each man.

Using both pumps nearly half an hour is needed for filling. The vehicle contains apparatus for applying the Horrocks test to water. By this test can be ascertained the amount of sterilizing powder required to sterilize a given quantity of water.

Full instructions are given with each vehicle and in Military Engineering, Vol. VI.

ii. Although the water cart will be used in the first instance and for temporary halts, arrangements must be made at the first opportunity to establish water points where safe water can be drawn. These are dealt with in Sec. **133.**

The arrangements for purification are usually as follows.

4. *Sedimentation.*—If a quantity of alum is added to water a gelatinous precipitate is formed which will carry impurities with it to the bottom of the tank. The amount required varies according to the impurity of the water from 0·5 to 5 grains a gal. The exact quantity can be found by experiment, but is usually about 1 grain a gal. or 1 lb. for 7,000 gals.

The time required is usually about 8 hours.

In the field the normal practice is to pump the water from the source into a tank where it remains for 8 hours after adding the alum before being drawn off. If a continuous supply is required it is, therefore, necessary to have two or more sedimentation tanks.

The outlet of a sedimentation tank should be a few inches above the bottom in order to be clear of the sludge. The sludge requires periodical removal. To facilitate this a scourpipe should be provided and the bottom of the tank should slope towards it.

5. *Purification.*

i. *With sterilizing powder.*—In the field the normal chlorinating agent is sterilizing powder, added as a solution to the water under treatment.

A contact period of 30 minutes must elapse after water has been chlorinated before it can be considered safe to use.

In order to ensure that water is not drawn off before the contact period has elapsed in cases where it is chlorinated close to the service reservoir or where the latter is small, it is advisable to pass the water, after chlorinating, through a contact tank where it will remain for 30 minutes. A convenient arrangement is to provide three tanks, each having a capacity equal to half an hour's pumping or flow of water ; the tanks are filled alternately and, after 30 minutes has elapsed, are allowed to empty into the service reservoir.

ii. By *ammonia-chlorine* process (chloramine).—In this method, which is likely to be adopted as the service method, a dose of ammonia is administered to the water before the dose of chlorine. The advantage of this method is that it is possible to introduce a standard dose for all waters, thus eliminating the necessity for carrying out Horrocks' test. Further, no unpleasant taste is left. The service agents are :—

(*a*) Ammonium chloride, supplied in tablets.
(*b*) Chlorosene, supplied in powder form.

The standard dose is two tablets of ammonium chloride and two scoops full of chlorosene to every 100 gals. of water. The scoops are contained in the boxes containing the powder and measure two grammes.

The chlorine dose must not be added before the ammonia dose has become well mixed with the water.

A contact period of one hour is required before the water is fit for drinking.

6. *Sterilization of well water.*—When a well is the source of supply and the water cannot be pumped into storage tanks for chlorination the following process can be adopted.

Measure the quantity of water in the well and carry out Horrocks' test on a sample of it.

If the test shows twelve scoops for every 100 gals. make up in a tin a paste of *n* plus 1 scoops, for each 100 gals. in the well. Raise it and lower it rapidly in the well several times until the paste has been washed out of the tin. An extra string to tip the tin in the well will be of assistance. This should be done at night and the water tested in the morning. If no free chlorine remains, one scoop for each 100 gals. should again be added. If the well is used much the water should be tested hourly and if the free chlorine falls below ½ part in a million another ½ scoop for each 100 gals. should be added. By this method an intelligent warden can supervise three or four wells if they are not too far apart.

7. *Sterilization in small tanks, e.g.* petrol tins and tanks of less than 100 gals. capacity.

i. By *chlorination.*—Carry out Horrocks' test. Place in the black cup the number of scoops of water sterilizing powder required for 100 gals. of water as shown by the test ; make into a paste and fill to the mark.

Of this solution in the black cup add one scoopful to each gallon of water to be sterilized.

ii. *By ammonia chlorine* process. Dissolve two tablets of ammonium chloride in a black Horrocks cup and two scoops of chlorosene in another.

One scoopful of each solution is added to each gallon of the water to be tested, *the ammonia solution being added first.*

8. *Sterilization of water in water bottles.*—The process is similar to the above, but in (i) after making the solution in the Horrocks cup pour it into a water bottle and fill up with water. Add one scoop from this bottle to each bottle to be sterilized ; in case (ii) pour each solution into a water bottle and fill with water. Then add one scoop from each to each water bottle to be sterilized, *the ammonia being added first.*

9. *Improvised plant.*

i. Normally, a purification plant will consist of tanks for sedimentation, for sterilization and for storage of purified water together with the necessary piping, pumps and apparatus for introducing the sterilizing agents.

The erection of tanks requires more time than any other part of the plant and their size should therefore be kept to a minimum. Pumps may be difficult to obtain and it will be necessary to take advantage of the natural features in order to obtain, as far as possible, gravity flow through the plant or, alternatively, to use the same pump for the various stages of purification. The actual lay-out will, therefore, vary according to local conditions.

ii. As sedimentation takes 8 hours, to allow for filtering, emptying and occasional cleaning after about 14 fillings a sedimentation tank will, on an average, sediment twice its own capacity every 24 hours. One tank may be sufficient or two or more may be required. Sterilization may be done in the purified water reservoir or in contact tanks. In the former case as ½ hour or 1 hour must elapse, according to the method used, before water may be drawn off on each occasion that water is admitted to the reservoir, a continuous supply cannot be maintained. By using two reservoirs and using alternately a continuous supply can be obtained.

iii. A plant to supply about 6,000 gals. of treated water a day from very unsatisfactory sources is shown diagrammatically in Plate **187**. The upper tank B is for alum sedimentation. The oil drum A contains the alum solution which is mixed with the incoming water. Tank C is for the purified water and the water sterilizing powder is contained in the oil drum D. Water for C can be pumped after ½ hour into storage tank E which is fitted with bibcocks.

If the ammonia chlorine treatment is used ammonium chloride solution is made up in another oil drum and introduced at F. Chlorosene is then used in D.

iv. A design of somewhat more permanent character is shown in Plate **188.** In this case the overhead tank is connected to a water-cart point of the usual type. The method of adding the sedimentation and chlorinating agents is as before.

To operate the plant the sedimentation tank is filled with crude water, valves A and E being open and valves B, C and D shut.

At the same time as the pump is discharging water into the trough an appropriate amount of alum is let in from the alum tank. After the period required for sedimentation valves A, E, and D are closed and valves B and C are opened. Enough clarified water is pumped through to clean the pump, the water running away to the drain, and valve D is opened and valve C is closed. The clarified water is then pumped up into the elevated tank where it is sterilized. Full details of these and other methods are contained in Military Engineering, Vol. VI.

131. Protection of the source from fouling

1. Small collections of water, such as ponds and streams in inhabitated places, are never fit for drinking without purification. The following precautions should be taken :—

i. Latrines, etc., must be sited so that they cannot drain into the supply.

ii. Places from which drinking and cooking water are taken should be selected where there is least likelihood of stirring up the water.

iii. Bathing and washing in ponds must not be permitted.

iv. Animals must be kept from ponds by a rough fence. They must be watered by buckets or troughs.

v. Watering places must be policed.

2. If water is obtained from a stream, horses will be watered below the place where troops obtain their drinking water, but above bathing and washing places.

Patrolling by mounted men will be necessary for some distance above the drinking water supply. This latter should be well upstream from the camp. It should be at a place where the current is good and the depth is considerable, and should be protected.

If the water is to be got out by dipping in buckets, etc., a barrel with holes in the side, or a gabion with stones in the bottom, should be sunk in a vertical position, so that the dipping will not stir up the mud. If the water near the bank is shallow a wooden gangway should be made out to a part deep enough for dipping.

Where animals are to drink, a hard bottom of gravel or stone should be made, with water from 4 to 6 in. deep over it. If the sides are steep, a ramp by which the animals will approach should be made straight down to the water, and they should leave by ramps downstream (since animals water head downstream) so as not to interfere with other animals coming to drink. If necessary, a barrier should be erected to prevent animals going too far out into the water.

If other troops are using the river lower down, special arrangements must be made for washing, and for watering animals away from the river.

3. All wells should be protected by a fence enclosing an area of not less than 25 yards diameter; in the case of springs on a slope, protection need only be at the sides and above.

The following steps should be taken to protect a well from contamination :—

i. The mouth should be one or two feet above the level of the ground, and the ground should be sloped outwards.

ii. The mouth of a small well should be closed with a tightly fitting cover with a manhole in it.

iii. The pump should be placed directly over the well near the inside edge, the water being pumped to tanks outside the fenced area, chlorinated, and drawn off by taps.

If there is no pump, one or more buckets must be set apart for drawing water, and no other vessels allowed to be put into the well.

Where more than one spring or well is to be used, the best should be reserved for drinking water; water for animals and ablution being drawn from the remainder.

Washing must never be allowed at springs or wells used for drinking purposes.

4. Springs should be protected in a similar way to wells. The water from a spring should be led directly into a closed tank, chlorinated, and drawn off by taps. Failing this, a

spout should be arranged so as to obtain the water from the spring. In no case should it be collected in open vessels or in hollows scooped in the ground for, if this is done, the water is certain to be fouled by drainage, or by men washing in it or dipping in dirty vessels.

If, for want of time, springs cannot be adequately protected, a special water party must be detailed to fill the vessels, all other persons being kept at a distance.

132. Methods of storing water

1. The storage tanks and troughs normally available in the field are given in Table 23 and Plates **189** to **193** and described later in this section.

2. When erecting any tank or trough, see that it stands on level ground; otherwise its capacity will be diminished.

3. *Tank, waterproof* (*capacity* 1,500 *gals.*). (*See* Plate **189.**)—Drive the sixteen posts at intervals of 2 ft. 9 in. to form a square of 11 ft. by 11 ft. The top of the posts should be 2 ft. 11 in. above ground level. The hooks on the posts must be on the inside.

Lash the 3-in. rope round the edge of the sheet with the ¾-in. rope.

Draw the sheet into shape by gathering the edge along the 3-in. rope, and knot the ends of the latter together.

Hang in position by resting the 3-in. rope on the hooks.

Canvas water tank—self-supporting. (Plate **190.**)—This tank is circular with slightly conical sides and an open top surrounded by a ring float of kapok. A cover is provided which serves to cover the tank when full and to wrap the tank when folded for transport.

Its capacity is 1,500 gals. and it weighs 83 lb. when dry. When wet it weighs about double.

4. *Trough, waterproof* (*capacity* 350 *gals.*). (Plate **191.**)—Set up standards eight eyelet holes apart. The tracing line is rove over the edge of the sheet, and through the eyelets. At the corners, pass the line through the third eyelet of both side and end. Fold the overlap round the end standard, and lace to the side of the trough. With Mk. I pattern standards, hook all standards except the end ones into the eyelets. With Mk. II standards, rest the line in the groove at the top of each upright (Plate **191**).

Drive the four pickets, two at each end, in line with the sides, and 6 ft. beyond the end of the trough. Lash the top of the end standards to the foot of the pickets with the four 1½-in. lashings.

See that trough and tracing lines are taut before filling.

TABLE 23.—STORAGE TANKS

Description (1)	Capacity gals. (2)	Floor space (3)	Stores (4)	Weight lb. (5)	Remarks (6)
Tank, waterproof.	1,500	11 ft. × 11 ft. (*b*)	Sheets 16 ft. 9 in. × 16 ft. 9 in. (*a*) Posts, picket, 5 ft., 16. Rings, hook, for posts, picket, 16. 3-in. white rope, fathoms, 10. ¾-in. white rope, fathoms, 25.	60 325	(*a*) Double cotton, with rubber between, fitted with brass eyelets, and strengthened at edges with a small rope.
Covers, black, waterproof.	8,000	30 ft. × 30 ft.	*See* Sec. **132**, 5.		At least 2¼ ft. deep. Allows 6 in. freeboard and 5 ft. depth. Will hold about 10,000 gals.
Steel tanks.			*See* Military Engineering, Vol. VI.		
Trough, waterproof.	350	45 ft. × 2 ft. (*b*)	*Horse Troughs.* Sheets, 36 ft. × 5 ft. (*a*) Posts, picket, 2 ft. 6 in., 4. Tracing line, 1. Lashings, 1½ in. by 30 ft., 4. Standards (1 set), 10.		(*b*) Length includes pickets. For distribution only.
Trough, water.	48	5 ft. × 1 ft. 6 in.	Trough (*c*). Posts, picket, 5-ft., 4.	13 lb. 6 oz.	(*c*) Sail canvas, strengthened by rope. Shape maintained by elm pieces.
Canvas water tank, self-supporting.	1,500			83 (dry)	

5. *Covers, black, waterproof.*—With a 30-ft. by 30-ft. cover, a storage tank of 7,000 to 8,000 gals. capacity can be made (Plates **192** and **193**).

If covers are not tarred, this can be carried out as follows :—

- i. Sheets must be tarred under cover.
- ii. Spread sheets on a hard surface ; brush to remove dirt before applying tar.
- iii. Use a tar-spraying machine if obtainable ; otherwise use a long-handled tar brush. The tar must be used boiling.
- iv. After spreading, rub the tar into the sheet with a hand scrubbing brush. Use as little tar as possible, and get it well into the pores of the material : a skin of tar is not wanted.
- v. After tarring one side, hang up to dry under cover. Do not apply a second coat until quite dry.
- vi. At least one coat each side must be applied and, if possible, two coats.
- vii. The mixture used must be genuine Stockholm tar, with the addition of sufficient pitch to make it easily worked, *i.e.* 1 lb. of pitch to 1 gal. of tar is sufficient for 100 sq. ft. in the first coat, and 150 sq. ft. in the other coats.

Common mistakes :—

- i. Tar not boiling : adheres only in patches.
- ii. Insufficient bristles in tar brush.
- iii. Men walk on sheet in muddy boots while tarring.
- iv. Sheet tarred in open, and work spoiled by rain.
- v. Second coat applied too soon ; resulting in a slimy coating which never dries.
- vi. Sheet fixed in tank first, and then tarred. Consequently water leaks under the folds.
- vii. First filling of water run into supply mains instead of to waste, resulting in the water being tainted by the tarpaulin.

6. A quicker method of rendering canvas waterproof is to use tallow dissolved in boiled linseed oil, as under :—

- i. Mix the tallow with boiled linseed oil in the proportion of 1 lb. to the gallon, and apply with a soft brush.
- ii. Apply two coats. The first coat will take about 12 hours to dry ; allow a further 12 hours before applying the second coat.
- iii. About ¼ gal. of the mixture for each 100 sq. ft. will be required for each coat.

7. Plates **193** and **198** show the method of construction for raised canvas tanks. It is not generally advisable to make the tank more than about 3 ft. deep. It is important that the canvas be quite slack, and it must not bear on any sharp edge or nails. The sides of the tank must be well strutted, and there must be a light footboard all round for cleaning purposes. Raised tanks as shown should always have a washout connection fitted and a light cover to keep out dust and flies. This will usually consist of hessian canvas on rabbit netting, supported on galvanized iron wire stretched across the tank.

8. Ground level framed tanks can be made as shown on Plate **192.** Convenient sizes are :—

- i. 8,000 gals., using a 30-ft. by 30-ft. tarpaulin.
- ii. 2,000 gals., using a waterproof tank.

9. If unskilled labour is plentiful, however, it will often be quicker and more satisfactory to construct sunk tanks as shown in Plate **189** with earth banks.

When bricks are plentiful, sunk tanks may be constructed as shown on Plate **194.** A light roof of timber framework supporting a rabbit wire and hessian canvas covering should be provided. The canvas should be tarred to keep dust from working through, and a manhole fitted to allow access for cleaning.

It is possible to build a tank of this type in seven days. Materials required :—

Cement	1½ tons.
Bricks	2,000.
Rabbit wire	1,150 sq. ft.
Canvas...	750 sq. ft.
Timber, 4 in. × 2 in. ...	220 ft. run.

10. All storage tanks must be frequently emptied and cleaned, a strong solution of water sterilizing powder being used.

11. When tanks and troughs are not available, the following expedients can be adopted :—

- i. Streams can be widened and deepened, and all water diverted into one channel.
- ii. Streams can be dammed (*see* Sec. **140**), so as to raise the water-level : a small channel can be dug along a hillside or bank for animal watering.

133. Methods of distribution

1. After raising and purifying water it has to be distributed to consumers.

Methods of distribution may vary from the simplest, when drinking and cooking water are distributed through the unit water vehicles, Plate **195,** and animals are watered from the stream, to the most elaborate, where water is distributed from storage tanks through a system of pipe lines to distribution points. Between these two extremes are many other variations. The system adopted will depend mainly on (i) the time available for preparation, (ii) the time for which the water will be required, (iii) the stores available and other local conditions. Piped systems are dealt with in Military Engineering, Vol. VI.

Some of the other variations are discussed in the following paragraphs.

2. *Water points.*—For temporary supply it is desirable to distribute water from a few definite points as far as possible central to the area of consumption. These are known as water points.

There are two types of points for distribution of drinking water.

i. Dixie and water-bottle filling point.
ii. Water vehicle point.

In order to provide a continuous supply it is necessary to provide *storage tanks* in addition.

3. *Types of distribution plant.*—

Plate **187** illustrates a temporary plant on the banks of a stream. It is described in Sec. **130.**

Plate **188** illustrates a more permanent plant with elevated storage tanks. As explained above these tanks may have to be duplicated. This is described in Sec. **130.**

4. *Dixie and water-bottle filling points.*—Plate **196** illustrates typical details. These points should be close to consumers to reduce the length of carry. Bibcocks for water-bottle fittings must be ½-in.

5. *Vehicle water points* may be anything from a petrol or hand-pump at the roadside to a complete point as illustrated in Plates **197** and **198.**

Points to note.—

i. Standpipes must be 30 ft. apart.
ii. There should, if possible, be 5,000 gals. storage for each standpipe.
iii. Points must be sited close to roads but off the main traffic route so that vehicles waiting will not impede traffic.

134. Transport of water

1. Where no local supplies exist, and piped supplies cannot be arranged, water must be carried in bulk, either in ships, barges, railway trucks, lorries, etc., or on camels, etc.

2. Arrangements include :—

i. *Initial water points* at which vehicles can fill.
ii. *Spill tanks* to which vehicles deliver water for final distribution as previously explained.

3. Initial water points. Requirements :—

i. Elevated storage tanks, placed near and above the road or track (rail, canal, etc.), used by water vehicles (*e.g.* top of a cutting).
ii. Standpipes, or hoses leading direct from the bottom of storage tanks, through which vehicles are filled by gravity.

The number and spacing must be such that a string of vehicles can fill simultaneously, and the storage such that the tanks need refilling only between strings of vehicles. For details, *see* previous sections and Military Engineering, Vol. VI. In general, the principles are the same as for the vehicle water points described for men's drinking water.

4. *Spill tanks.* Requirements :—

i. Storage capacity to suit vehicles emptying into them.
ii. Tanks must be near, and below, tracks used by vehicles (*e.g.* bottom of an embankment). They must be arranged so that water can be discharged into them by gravity. If necessary they must be sunk in the ground. In forward areas, during protracted defence, this must be done to protect tanks from shellfire. Spill tanks should have covers.
iii. When water is transported by sea or canal, and gravity emptying is impossible, large power pumps must be installed.

5. *Pack transport.*—Arrangements must be made to water the pack animals as well as providing convenient platforms for loading water vessels on convoys.

A camel carries two tanks, each holding 12 gals. These tanks are an article of store.

A mule carries eight 2-gal. petrol tins, arranged in wooden racks. (*See* Military Engineering, Vol. VI.)

Skins and water bags may also be used.

Bags made of waterproof sheeting for pack transport are articles of store.

Canvas bags, with double and close stitched seams, become watertight after a few days.

135. Quantities of water required for men, animals and M.T. vehicles

1. This can be calculated from Tables 24A and 24B.

2. If the *daily* yield of the source selected is sufficient to satisfy the above requirements, the requirements as to quantity are fulfilled.

3. The next point to consider is the rate at which consumers will draw water. For example, as regards horses, calculate that a horse will drink **5** gals. at one watering, and that watering should not take longer than one hour. If the *hourly* yield of the source is greater than this, the only question that remains is the capacity of the pump to raise the water at this rate.

4. If either the hourly yield or the hourly capacity of the pump is less than the required rate, storage tanks, holding at least sufficient water for one watering, must be installed; pumping will be continued between waterings.

5. The supply must then be allotted, and marked as follows:—

  i. Men's drinking and cooking water—white flag.
  ii. Animals—blue flag.
  iii. Men's washing—red flag.

It is necessary to protect the source from fouling. (*See* Sec. **131**.)

136. Animal watering arrangements

1. The distribution unit for the animal is :—

One lift and force pump, complete with accessories as shown in Sec. **129**.

One trough, waterproof, capacity about 350 gals.

Normally this unit can water 144 horses an hour allowing 4 ft. run for each horse, and seven minutes a batch, including time for change-over. In emergency the speed can be increased by reducing the footage for a horse.

Only 18 camels can use the trough at once, and each batch takes twenty minutes to water.

Watering should be completed in one hour. If the number of troughs carried will not permit this, improvised troughs must be made.

Designs for more permanent types of horse trough and water point are given in Plate **199**.

TABLE 24A.—DAILY REQUIREMENTS—TEMPERATE CLIMATES

(1)	(2)	(3)	(4)
		gal.	
Man.	Absolute minimum.	½	On the march, periods not exceeding 3 days.
	Minimum for drinking and cooking.	1	At rest, for periods not exceeding 3 days.
	Minimum for all purposes.	2	At rest, for periods not exceeding 3 days.
	Normal for drinking, cooking and washing.	5	This is the *minimum* figure which it should always be the *aim of the R.E.* to supply.
	Temporary camps with baths.	15	*E.g.* staging and rest camps.
	Normal for all purposes.	30	Permanent cantonments with water-borne sewage.
	Normal for all purposes.	50	Town supplies.
Horse, mule or ox.	Normally.	10	It is possible for a horse to go 48 hours without water; it usually drinks 3 gals. at a watering, but may drink 5 gal. at mid-day or evening. The latter figure should be taken in calculating requirements. A horse takes 5 mins. to drink, *i.e.* time including change over is 7 minutes.
	Absolute minimum.	3	
Sheep or pig.		1	
Camel.		10	Allow an extra 10 gal. every third day. A camel takes 20 mins. to water, and drinks in two bouts with an interval of 10 mins.

TABLE 24B.—MISCELLANEOUS CONSUMPTION FIGURES

Each slipper bath	200 gal. a day.
Each shower bath	300 gal. (allowing 2 hours bathing, 12 baths an hour).
Benn sprayer bath	100 gal.
Each vehicle washed	10 gal.
BOILERS, STEAM RAISING.	
Locomotives, broad gauge, large	7,000 gal. a day, or allow 120 gal. each train mile (one engine each train).
Locomotives, metre gauge, small	2,500 gal. a day.
Locomotives, 60 cm. gauge	1,800 gal. a day.
Horizontal stationary type, compound, modern engine	2 gal. each H.P.-hour.
Horizontal stationary type, non-condensing	4 gal. each H.P.-hour.
Boilers, washing out	About 20 gal. each H.P. each washout under normal conditions at 50 lb./sq. in. pressure. Locomotives require about 3,000 gal. every 7 or 14 days.
Condensing water	At normal temperature, and sent to waste—100 gal. each H.P.-hour.
Petrol and oil engines cooling	Loss about ¼ to ½ gal. each H.P.-hour. Calculate at 7 gal. each H.P.-hour. Provide 35 gal. tank capacity each B.H.P.
RADIATORS OF VEHICLES.	CAPACITY.
Two-seater car	2 gal.
Cars, vans, ambulances, light lorries.	6 gal.
3-ton lorries	10 gal.
Light tanks	3½ gal.
Armoured cars—	
Rolls-Royce	9 gal.
Lanchester	15 gal.
Tractors—	
3-ton	14 gal.
30-cwt.	8 gal.

2. When water has to be rationed, either :—

i. Fill troughs to a definite level and allow a batch to drink it dry. Allow twice the normal time for watering, since pumping can only proceed during change-over. Empty troughs are more liable to damage than full ones. Protect sides thoroughly.

ii. Water from buckets. This ensures that each horse gets a fair share. Difficult to arrange for a large number of horses. No method based on time limit is likely to be successful.

3. Points to remember when arranging a horse watering point are :—

i. Where large numbers of horses are to be watered at one point, traffic control is difficult.

Therefore always try to arrange a large number of small water points. If impossible, see that traffic control is made as easy as possible by arranging for ample space for units waiting to water, seeing that the timetable is on the pessimistic side, providing ample fencing and sign-posting, etc.

ii. Keep the water point away from main roads.

iii. When a water point is to be used for any length of time, hard standings are required.

Hard standings are rapidly destroyed if mud and slime are brought on to them. Therefore the water point must be near a road that horses must use in wet weather. Horses may be allowed to come across country to the water point in dry weather. Separate " wet " and " dry " weather entrances and exits must be arranged.

iv. Erect separate troughs for sick horses, and for civilians' horses. Horses and camels must never use the same trough.

v. Troughs must be at least 30 ft. apart.

vi. Sides of troughs must, in all cases, be protected from the animals using them.

137. Washing arrangements

1. Men must not be allowed to wash in the storage tanks or horse troughs or nearer than 30 yards from the sources of water supply.

2. They must bring with them tins or buckets, and having filled these from the standpipes or cistern, they must go to the appointed place to wash.

3. Ablution benches (Plate **200**) should be made as soon as possible and drains provided (18 ft. run for each 100 men). For further arrangements, *see* Army Manual of Hygiene and Sanitation and Military Engineering, Vol. VI.

138. Well sinking

1. Wells up to 15 ft. depth are dug by hand. Boring is the best method for deeper wells, but hand digging may be necessary.

Normal dimensions of shaft are 4 ft. by 4 ft. for wells up to 50 ft. depth; for greater depth, 6 ft. by 6 ft. In fine sands, etc., the diameter may have to be 10 to 15 ft. to obtain sufficient flow.

2. *Excavation.*—By pick and shovel.

Only one man can work at the bottom. Windlass and tub are required for lowering men and tools. Fan and hose are needed for ventilation where the depth exceeds 130 ft.

3. *Steining.*—Chief varieties are :—

- i. Brick or masonry. Best for wells over 8 ft. diameter. (*See* Military Engineering, Vol. VI.)
- ii. Timber and corrugated iron tubbing. (*See* Plate **201.**) Suitable for wells up to 8 ft. diameter. For greater diameter cross bracing is needed. Use 3-in. timber for bracing.
- iii. Timber frames, 4 ft. by 4 ft., or 6 ft. by 6 ft. Shaft is sunk as mining shafts.
- iv. Steel tubbing. (*See* Military Engineering, Vol. VI.)

Tubbing is best for wet or treacherous soils. See that the first few tubs sink evenly, or they will eventually jam. .

4. *Finishing the well.*—The water must be kept down by pumping until the well reaches the required depth.

When finished, the top of the well must be protected from fouling.

139. Well boring

1. Drilling is a highly technical operation and must be in the hands of experts provided with suitable equipment.

In field operations time is the ruling factor. The time taken to sink a borehole will vary with the hardness of the earth formation and depth of bore. A drill crew working in two shifts of 8 hours each on a 6-in. diameter borehole in chalk can drill a 300-ft. borehole in three or four days.

2. There are two distinct systems of boring :—

- i. The percussion system.
- ii. The rotary system.

The percussion system employs a heavy chisel bit with a vertical up and down motion, similar to the jumping bar of mining and quarry practice.

In the rotary system a circular cutter is revolved.

For work with a field army the percussion system is used as the rotary method is too slow.

The most suitable plant for work with a field army has been found to be of the type described as the portable American rig.

These rigs are self-contained portable drilling plants, capable of drilling down to a depth of 1,000 ft. For details, *see* Military Engineering, Vol. VI.

140. Dams

1. Streams and rivers may be dammed in order to conserve water in long reaches for use during dry periods.

2. Timber and earth are the only materials suitable for field use. Particulars can be found in Military Engineering, Vol. VI.

3. An earthen dam must never be used as a weir-dam. A spillway must be made of timber or other material below the level of the top of an earthen dam. The earth must be so compacted that no water can pass through as a stream, however slight; further, there must be no continuous smooth surface, such as a pipe, through the dam, or water will leak along the joint.

Short dams can be built up to about 20 ft. high in the field. The inside slope should be 1 in 3, and the outside not more than 1 in 2 or 2½.

For embankments up to 10 ft. high, the top should be 3 to 4 ft. thick; up to 20 ft. high, 6 to 8 ft. thick. It should be 3 ft. above the water-level.

Drainage gutters may be necessary in the outside slope.

141. Fitting and laying W.I. pipes

1. *Sizes of pipes.*—In the field, pipes of 6-in., 4-in., 2-in. and 1-in. inside diameters are supplied. Other sizes are not normally provided.

Normally the 6-in. and 4-in. sizes will be victaulic (grooved) tube, and the remainder W.I. screwed tubing.

2. *The victaulic tube.*—

- i. This is similar to screwed piping except that the ends instead of being screwed are plain with either a shoulder or a groove cut in them. (Plate **202.**) The latter are more suitable for service use and will normally be employed. The grooves can be cut in the field, on screwed pipes if necessary.
- ii. Advantages compared with screwed piping :—
  - (*a*) Rapid laying. 3-in. victaulic can be laid about four times as fast as similar screwed with six men instead of nine.

(*b*) Jointing is easy: fitters need not be highly skilled.

(*c*) No threads to get damaged.

(*d*) Joints allow expansion and contraction.

(*e*) Joint is flexible, hence pipes can follow contours. Permissible deflection—4-in. pipe 2 to 3 degrees, 2-in. pipe—10 degrees.

(*f*) Any joint can easily be disconnected for repair work.

(*g*) Watertight and self-sealing.

(*h*) Also used for connecting pipe fittings.

iii. The joint consists of a hollow collar containing a rubber ring. The collar is in two segments which in old patterns bolt together; in new patterns they are fastened with a toggle joint and the rims fit into grooves cut round the ends of each tube. (Plate **202.**)

Tools required are a box spanner, crowbar, and pipe grooving machine.

iv. When laying victaulic tubing :—

(*a*) Smear inside of rubber ring where it touches pipe, and the outside where it engages with the housing, with graphite paste or similar lubricant. Soft soap, vaseline, or water can be used in emergency.

(*b*) In fitting joint first stretch ring on one pipe end; bring adjacent pipe into position, centralize ring; bolt housing carefully over ring seeing that ring is not nipped. When refitting a joint which has been laid over three months, use a new ring; if none available, soak old one in warm water to soften. See that tube ends are free from rust, scale, grit, etc., before assembly of joint.

(*c*) Instal pipes with ends almost butting. Lay as straight as possible. Use *setting pieces* to change direction.

(*d*) Anchor bends and tees, especially top bend of vertical mains.

(*e*) Where considerable expansion is expected, lay alternate pipes with ends butting; remainder with maximum gap.

(*f*) Clearance in joints and supports must allow for movement which takes place under pressure.

3. *W.I. screwed tubes.*—Each pipe has a socket on one end and a protector at the other.

Pipes are screwed to less than half the length of socket so that they will not butt when joined up.

Pipes are not supplied in standard lengths, but average lengths and weights of pipes are :—

6-in. pipe, length 18 ft., weight 240 lb.
4-in. pipe, length 17 ft., weight 175 lb.
2-in. pipe, length 20 ft., weight 88 lb.
1-in. pipe, length 19 ft., weight 40 lb.

Pipe tools.—The following tools are required for pipe work—cutters, dies, vices, wrenches.

When using dies and wrenches they should be rotated by downward pressure. If pulled upward a slip may rupture a man.

Bending pipes.—Bends of various angles are supplied from stock and can be used when circumstances permit.

When laying a pipe line with easy bends the pipes can be bent without heating.

With a sharper bend they should be bent in the fire by heating from 4-ft. to 8-ft. lengths at the point required. A wood fire is suitable.

On reaching a bend in the trench the next two or three lengths of pipe are screwed on to give leverage and the line bent round to the required degree, using crowbars to hold if necessary.

Connectors are used to join up two lengths of pipe that are already laid.

A connector is a piece of pipe cut to a convenient length (say 6 ft., 4 ft., 2 ft.), with a backnut and long thread at one end. The thread must be long enough to take the whole socket and backnut.

4. *Laying W.I. pipes.*—

i. *Preparation of pipes before laying.*—Look through every pipe to see if blocked. Unscrew socket, reverse it, and screw home on the other end of pipe using red lead. Screw protector on. This will ensure that all threads and sockets are in good order before starting to lay.

ii. *Laying.*—Rapid pipe-laying calls for very careful organization both of labour and stores. The following parties should be provided in the order named.

(*a*) *Laying out party.*—Officer or responsible N.C.O. locates line and marks with pegs. Gradual curves should be avoided. It is better to use a series of straights connected with easy bends. If laid on surface slightly wavy lines should be laid to allow for expansion and contraction. Position of valves, tees, etc., marked with notice boards.

(*b*) *Carrying party.*—Lay pipes alongside but clear of location. "Specials" are placed where marked. Suitable parties:—

6-in. pipe—6 men for each pipe.
4-in. pipe—4 ,, ,, ,,
3-in. pipe—3 ,, ,, ,,
2-in. pipe—2 ,, ,, ,,

(*c*) *Excavation party.*—Concurrently with (*b*) excavate trench 1½ to 2 ft. wide according to depth. 3-ft. of cover is required as protection against shells and frost. Spoil is thrown on one side only. Bottom of trench is smoothly graded.

(*d*) *Pipe-laying party.*—This follows (*c*) and consists of one or more squads according to requirements. Suitable parties:—

Size of pipe inches	Party	Tools	Progress in 8-hour day
6	1 N.C.O.—16	5	800 ft.
4	1 N.C.O.—11	4	1,000 ft.
3	1 N.C.O.—9	4	1,200 ft.
2	1 N.C.O.—7	2	2,000 ft.

Each squad should contain 2 pipe fitters.

Practical details.—Screw pipes well home into sockets and each equally into common socket. Red lead and oil should be used in each joint. Great care should be taken to see that pipes are laid clean. Pipes should not be screwed together whilst resting in their bed. The end of the pipe line should be raised on crutches by means of a rope sling and crossbar whilst screwing. See that threads are well protected during transit. Plug end of pipe which is to be left for any time.

A pipe laying cradle that will facilitate laying is described in Military Engineering, Vol. VI.

(*e*) *Making good party.*—This completes special fittings, adds frost protection, etc. Pipe-laying party stops a length or two short of a fitting and starts again the same distance after it. Making good party connects up. Joints are tested before covering up.

(*f*) *Filling in party.*—This fills in after test. Responsible that there is sufficient cover everywhere against frost, banking up if necessary. Collects surplus pipe and marks positions of mains and fittings. Wooden marks should not be used.

5. *Laying victaulic piping.*—The following organization for rapid laying of long lengths is suitable. Excavation party, making good party and filling in parties will be added if required.

Strength of party.

1 officer, 8 N.C.Os., 40 men, 2 lorries.

Nos. 1 *and* 2 *Squads*, each 1 N.C.O., 5 men, 1 lorry, lay out pipes along the line ahead of jointing parties.

No. 3 *Squad*, 1 N.C.O., 3 men, works ahead of the head of the pipe line joining up lengths of pipes into lengths of three pipes each.

Nos. 4 *and* 5 *Squads*, as for No. 3. These squads leap frog each other.

Nos. 6 *and* 7 *Squads*, each 1 N.C.O. and 8 men, work at alternate joints at the head of the pipe line, lifting the lengths of three connected pipes into the trench, working them into correct position and joining them up to head of pipe line.

No. 8 *Squad*, 1 N.C.O. and 5 men, prepare all pipe-joints for connection, including examination of all pipes for obstructions or damaged ends, preparation of housings and greasing of pipe ends and rubber rings.

The daily output of such a party should be 1 mile.

6. *Mending breaks.*—The location and mending of a break is always a long and troublesome job. Special connector sets containing pipes of various lengths from which any length can be made up are useful on a big job. Special repair sleeves which fit over a break are useful. They are caulked with hemp and filled in with lead wool. (*See* Military Engineering, Vol. VI.)

CHAPTER XXVII

WORK FOR THE ROYAL AIR FORCE

142. General

This chapter deals with the selection, preparation and maintenance of temporary landing grounds. Information about those of a more permanent nature and of aircraft depots and parks will be found in Military Engineering, Vol. VII.

143. Selection of landing grounds

1. In the case of an army co-operation squadron the chief consideration will be proximity to divisional headquarters and rapidity in constructing the ground. It will usually be a case, in Europe, of using grass fields, and all the work that can be expected will be the removal of portions of fence and the filling in or piping of a minimum length of any ditch. The air force should always be consulted before a final selection is made.

Factors requiring consideration in the selection of a suitable landing ground are :—

i. Dimensions and shape.
ii. Surface, slope and drainage.
iii. Air approaches and general surroundings.
iv. Meteorological conditions.
v. Communication, water supply, etc.

2. *Dimensions and shape.*—

i. The best shape is a square or rectangle.

ii. Normal minimum dimensions are 500 yards in any direction. If the ground is more than 3,000 ft. above mean sea-level (M.S.L.) or if used for night flying, minimum dimensions are 600 yards, and if over 6,000 ft., 700 yards. If air approaches are bad, the above dimensions should be increased (*see* para. 7, below).

If a rectangular ground is impracticable, an L or T-shaped ground may be chosen with arms of above dimensions in length and normally not less than 250 yards in width. When these dimensions cannot be obtained the largest dimension must be in the direction of the prevailing wind and the clearing of the air approaches must be specially arranged.

3. *Surface, slope and drainage.*—Surface of a landing ground should be free from furrows, ditches, small banks, and any sudden change in the degree of hardness of the soil and in the slope of the ground.

Stony ground, soft sand and soggy patches tend to overturn machines.

Where there is much rain, choose a permanent pasture with porous surface soil and well-drained subsoil.

All grounds should be capable of bearing weights of heavy aircraft.

The best slope is one sufficient to run off storm water without the formation of ruts, and no slope should exceed 1 in 50.

Gently undulating ground is permissible.

Area subject to ground mist or fog should be avoided.

4. *Air approaches and general considerations.*—A hedge or other obstruction on the edge of an aerodrome renders the ground to a distance of fifteen times the height of the obstruction useless for landing.

The remedy for this is :—

i. Increase the size of the aerodrome ;
ii. remove the obstacle, or cut in it a gap not less than 60 ft. and preferably 200 ft. wide.

Telegraph and other wires are invisible from the air, and they should be buried or removed from the vicinity of the landing ground.

The vicinity of steep hills is dangerous. However, a site on high-lying ground is good since there is :—

i. Freedom from fog.
ii. Simplicity of drainage.
iii. Usually lack of obstructions in air approaches.

Open fairly level ground round a landing ground, especially in the direction of normal wind, is an advantage as it makes forced landings safer.

5. *Communications, water supply, etc.*—Squadron and other formation aerodromes will normally only require good road access, but rail access will always be necessary for an aircraft depot with its workshops and stores. The usual water supply and camping facilities, as laid down in Parts I and II of this volume, will be necessary.

6. *Landing ground report.*—A landing ground report will always have to be prepared when selecting a new landing ground as follows :—

LANDING GROUND REPORT

i. Map reference.
ii. Description.

- (*a*) Dimensions.
- (*b*) Nature of surface, *e.g.* whether sandy, clay, stony, etc. If sandy, whether loose sand drifts with wind, and collects in lumps round scrub or grass.
- (*c*) Condition of surface, *e.g.* whether tendency to rut; existence of boulders, bushes, grass, if any, etc.
- (*d*) Slope and drainage, and condition during rains.
- (*e*) Possibilities of extension and work necessary.
- (*f*) Detail of all wires, trees, buildings, hills, ditches banks, etc., within 200 yards of the boundaries, giving their height and distances from the nearest edge of the ground.
- (*g*) Nature of surrounding country.
- (*h*) Time and labour required for making the ground, and for any suggested extension.

iii. Accommodation.

- (*a*) Camp sites.
- (*b*) Water supply.
- (*c*) Communications.

144. Levelling

Mounds or ditches on the landing ground should be levelled and re-turfed if the surface is grass. Any depressions caused by the grubbing and removal of internal fences are best filled up with soil; ditches should be piped before being filled up. Small depressions on a heavy landing ground are best filled with cinders.

2. If the selected site is under ridge and furrow, it can be dealt with in various ways :—

i. If the turf is good and the depressions slight, fill in the furrows with ashes mixed with loam an inch or two at a time, so as to allow the grass to grow through, and roll judiciously.

ii. With more pronounced ridges and furrows, the turf should be lifted, and the soil skimmed off the ridges and levelled into the furrows, and the turf then replaced and rolled. When filling the hollows, the addition of a small proportion of ashes is sometimes beneficial.

3. As a guide to the general smoothness and firmness of the ground, it should be possible to drive a car at 35 miles an hour on any part of the landing ground without inconvenience to the occupants, or alternatively it should be possible to drive a fully loaded 3-ton pneumatic-tyred lorry slowly over it without the wheels sinking in.

145. Marking of landing grounds

1. Markings are required to call the attention of pilots to the landing ground and to indicate the area on which it is safe to land.

A white circle 50 yards in diameter and 4 ft. wide is used to call the attention of the pilot. It is sited in the best area for landing, and is made by clearing the ground of grass and then white-washing.

2. Angle flats are used when time is available for their construction. From each corner of the actual landing area, a white strip 40 ft. by 4 ft. is laid in the direction of the next corner. The pilot then knows that the ground enclosed by the angle flats is safe for landing.

3. Portions of the ground temporarily unfit for use are marked with a white cross with arms 30 ft. long and 3 ft. wide. If the unsafe area is considerable angle flats may be necessary in addition to the cross.

4. No landing ground should be provided with any markings without the express approval of R.A.F. headquarters.

146. Maintenance of landing grounds

1. It is of the utmost importance that the surface of any landing ground should be maintained in good condition.

Furrows will be made by the tailskids of machines, and cattle or local traffic may cause ruts or holes, more especially after rain. All such damage must be repaired at once by filling in and rolling or ramming.

2. Rain damage can be reduced by efficient drainage.

3. Drifting sand is very troublesome, as it may collect to form dunes if it is caught by camel-thorn or the grass that sometimes springs up after a rainstorm. Dunes are most dangerous to aircraft, and the only remedy is to pull up the grass or camel-thorn and allow the sand to distribute itself.

4. Markings must be kept white and clear of vegetation.

5. Grass in the vicinity of buildings should be cut periodically to lessen fire risks, and should be kept down on the landing ground by grazing or cutting those parts most in use.

147. Accommodation on landing grounds

1. The provision of accommodation on landing grounds will vary considerably according to circumstances. In advanced

landing grounds liable to air attack, the main consideration is the concealment of the ground as much as possible. Aircraft will either be pegged out in the open at considerable distances apart to minimize damage from bombs or hidden in neighbouring woods, etc. The construction of stable traverses some 10 ft. high to protect individual machines will be undertaken as soon as possible.

These will have to be sited to avoid blocking the air approaches and in very wet weather some form of hard track will have to be made for the wheels at the entrances.

The front straight traverse should overlap the side walls of the stable.

2. It is unlikely that buildings will be constructed on forward landing grounds, though neighbouring billets in existing buildings will be certainly occupied both for stores, workshops, etc., and as accommodation for men. The most important requirement is good road access.

3. In the east and other countries where enemy bombing is unlikely, protection from heat and dust will be required. Hangars either in the form of tent hangars or special collapsible hangars will be sent up from the base to protect aircraft, with a specialist who will arrange erection with local engineer assistance.

Light huts will be built for offices, workshops and stores. The wireless cabin will probably be the most urgent of these. Designs will depend on material available.

4. Petrol supplies on field landing grounds will be mobile, *i.e.* either from petrol lorries or trailers or in cans and drums. Oil will be in drums.

5. Bombs will be stacked as convenient and covered with waterproof covers, with traverses constructed round groups.

Bomb components, pyrotechnics, and B.I. bombs will be kept under some form of cover if possible.

6. On landing grounds liable to air attack, everything will be scattered and concealed as much as possible. On landing grounds not liable to air attack, everything will be concentrated both for convenience and for local defence. When ground defence is required, the accommodation area will be surrounded with a barbed wire apron fence with machine-gun posts at the re-entrant corners.

In all cases of accommodation, etc., siting is important with a view especially to keeping the air approaches clear.

APPENDIX I

GENERAL INFORMATION

1. Tables of Weights and Measures

TABLE 25.—LINEAR FIGURES

(1)	In. (2)	Ft. (3)	Yds. (4)	Pls. (5)	Chs. (6)	Furs. (7)
Foot	12	1	—	—	—	—
Yard	36	3	1	—	—	—
Rod, pole or perch	198	16½	5½	1	—	—
Chain	792	66	22	4	1	—
Furlong	7,920	660	220	40	10	1
Mile	63,360	5,280	1,760	320	80	8
Fathom	72	6	2	—	—	—
Nautical or geographical mile	72,960	6,080	2,026⅔	—	—	—
Cable's length	7,296	608	202⅔	—	—	—
Millimetre	0·039	0·003	0·001	—	—	—
Centimetre	0·394	0·033	0·011	—	—	—
Decimetre	3·937	0·328	0·109	—	—	—
Metre	39·37	3·28	1·094	—	—	—
Kilometre	39,370·79	3,280·90	1,093·633	—	—	—

1 kilometre is approximately ⅝ mile; to convert miles to kilometres multiply by 1·609.
To convert yards to metres multiply by 0·914.

TABLE 26.—SQUARE MEASURES

(1)	In. (2)	Ft. (3)	Yds. (4)	Pls. (5)	Chs. (6)	R. (7)	A. (8)
Square foot	144	1	1	—	—	—	—
Square yard	1,296	1	1	—	—	—	—
Rod, pole or perch	39,204	272¼	30¼	1	—	—	—
Square chain...	627,264	4,356	484	16	1	—	—
Rood	1,568,160	10,890	1,210	40	2½	1	—
Acre	6,272,640	43,560	4,840	160	10	4	1
Square mile	—	—	3,097,600	102,400	6,400	2,560	640
Centiare	1,550·059	10·764	1·196	—	—	—	—
Are (100 square metres) ...	—	1,076·430	119·603	—	—	—	0·025
Hectares	—	—	11,960·333	—	—	—	2·471

To convert acres to hectares, multiply by 0·405.

TABLE 27.—CUBIC MEASURE

1,728 cu. in. = 1 cu. ft.
27 cu. ft. = 1 cu. yd.
1 cu. metre = 35·3156 cu. ft.

To reduce cubic feet to cubic metres, multiply by 0·028.

TABLE 28.—LIQUID MEASURE

(1)	Pts. (2)	Qts. (3)	Gals. (4)
4 gills	1	—	—
Quart	2	1	—
Gallon	8	4	1
Firkin	72	36	9
Kilderkin	144	72	18
Barrel	288	144	36
Hogshead	432	216	54
Puncheon	576	288	72
Butt	864	432	108
Litre	1·759	0·880	0·22
Hectolitre	175·976	87·988	21·997

To convert gals. to litres, multiply by 4·56.
A gal. of fresh water weighs 10 lb.

TABLE 29.—MEASURES OF WEIGHTS

(Avoirdupois weight.)

(1)	Oz. (2)	Lb. (3)	Qrs. (4)	Cwt. (5)	Gr. (6)
16 drachms ...	1	—	—	—	= 437·5
Pound	16	1	—	—	= 7,000
Stone	—	14	—	—	—
Quarter	—	28	1	—	—
Hundredweight ...	—	112	4	1	—
Ton	—	2,240	80	20	—
Gram	0·035	0·002	—	—	—
Kilogram	35·26	2·204	—	—	—

To convert lb. to kilograms, multiply by 0·454.

TABLE 30.—AREAS AND CONTENTS OF CERTAIN FIGURES

Circle	Radius (r) = $\frac{1}{2}$ of diameter (d). Circumference = $2r = d$ (= 3·1416 or $\frac{22}{7}$ nearly). Area = $r^2 = 0{\cdot}7854d^2$.
Triangle	Area = $\frac{1}{2}$ base × perpendicular from apex to base.
Cylinder	of height h—Cubic content = $r^2h = 0{\cdot}7854d^2 \times h$.
Cone	of height h—Cubic content = $\frac{1}{3}r^2h$ (r = radius of base).
Pyramid	of height h—Cubic content = $\frac{1}{3}h$ × area of base.
Sphere	of radius r—Cubic content = $\frac{4}{3}r^3$.

2. Weights of various items

Infantry in fours weigh 5 cwt. a ft. run of bridge.

Cavalry in half-sections weigh 3½ cwt. a ft. run of bridge.

18-pr. gun—maximum concentrated weight on one bay = 24 cwt.

4·5-in. howitzer—maximum concentrated weight on one bay = 26 cwt.

60-pr. gun—maximum concentrated weight on one bay = 67 cwt.

The weight carried by a dismounted man in marching order is approximately 61 lb. In fighting order, *i.e.* without pack but with 250 rounds of S.A.A. the weight is approximately 55 lb.

100 men in heavy marching order weigh about 9½ tons.

35 cu. ft. = 1 ton displacement (for boats, etc.).

A horse or big mule can draw, in a service vehicle and in fair country, 8 to 10 cwt. in addition to the vehicle itself; a heavy draught horse can draw a ton.

A pony or cob can carry 120 to 180 lb.

The following loads should not, as a rule, be exceeded :—

Forage cart, 1 horse	1,200 lb.
L.G.S. wagon, 2 horse	1,500 lb.
G.S. wagon, 4 horse	3,000 lb.
Weight of 1 cu. ft. of fresh water	62·4 lb.
,, 1 gal. of fresh water	10 lb.
,, 1 cu. ft. of loose earth...	80 to 100 lb.
,, ,, ,, pine	41 lb. approx.
,, ,, ,, fir	40 ,,
,, ,, ,, beech	43 ,,
,, ,, ,, oak	57 ,,
,, ,, ,, concrete or brickwork ...	120 ,,

3. Principal tools, materials, and stores suitable for use in field engineering

The tools and stores provided for the peace instruction of regular troops in field engineering are as laid down in Equipment Regulations, Part I, 1932, Chapter XIII, and Appendix 39. The tools and stores forming war equipment of units are similarly detailed in the various sections of Equipment Regulations, Part II, and in Mobilization Store Tables (A.F. G 1098) or War Equipment Tables.

The following tables of tools, materials and stores (Tables 31 to 45) are intended as guides for the selection and preparation of articles, suitable for use in war, for such operations of field engineering as are described or indicated in this manual.

The method of obtaining supply of such articles will follow the instructions laid down in Field Service Regulations, and Ordnance Manual (War).

The special equipment required for the following engineer services is not included in these tables, except in so far as certain articles comprised therein may be suitable for general field engineering purposes :—

Electrical instruments and electric light stores.
Railway tools, plant and armoured trains.
Survey instruments and stores.

Demand and issue, except where otherwise stated, are "per article."

TABLE 31.—TOOLS, ENTRENCHING

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
J.	Axes, pick, heads ...	4½ lb. and 8 lb.	
J.	,, ,, helves ...	36-in. ferruled and plain.	
J.	Barrows, hand, single	5 ft. 4 in. by 2 ft.	
J.	Barrow, wheel, entrenching with wheels.	Wood-wheels, flat tyre.	
F.	Crowbars	2 ft. 3 in., 4 ft. 1 in., and 5 ft. 6 in.	
W.1.	Picks, miners, heads	4½-lb. ; steel.	
W.1.	,, ,, helves	24-in.	
J.	Shovels, G.S.	32-in. helve, 3½ lb., curved.	
J.	,, R.E. ...	32-in. helve, 5 lb., curved and stout.	
W.1.	,, claykickers, Mk. I.		
W.1.	Shovels, miners, Mk. I		
W.1.	,, ,, helves	16 to 18 in.	
J.	Spades, Mk. III ...	32¾-in. helve, straight, 5¼ lb.	

TABLE 32.—TOOLS, CUTTING

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
F.	Adzes, carpenters, half-head 3¼-in.	—	
F.	Augers...	Sizes ¼-in. up to 2½-in.	
J.	Axes, felling	34½-in. helve, 4½ lb.	
J.	,, hand	16-in. helve, 2 lb. 2 oz.	
F.	Braces, carpenters ...	—	
F.	,, carpenters, bits	—	
F.	,, ratchet ...	—	
F.	Chisels, brick	18-in., 1¼-in. end.	
F.	,, cold	Metal cutting, ½-in., ¾-in., and ⅞-in. wide.	
F.	,, firmer ...	Woodcutting, blades 1/16-in. to 1¼-in. wide.	
W.1.	Cutters, wire, large ...	Long compound lever.	
F.	Files, saw taper, second cut, single.	4-in. for handsaw.	
F.	Files, smooth, three square.	8-in. for cross-cut.	
F.	Grindstones, F.S. ...	14-in.	
J.	Hooks, bill	—	
J.	Hooks, reaping ...	—	
F.	Oilstones	—	
F.	Pliers, side-cutting ...	5-in., 6-in., 7-in., and 8-in.	prs.
F.	Rasps, carpenters ...	Second cut, half-round, 8-in., 10-in. and 12-in.	
F.	Saws, cross-cut ...	3-ft. and 5-ft.	
J.	,, folding, in leather case.	—	
F.	Saws, hand	26-in.	
F.	Sets, cold, with eye	Handled; for cutting steel wire rope, etc.	
F.	,, saw, hand ...	—	
F.	,, ,, pit ...	—	
F.	Stones, rag, farriers ...	—	

TABLE 33.—TOOLS AND STORES, MISCELLANEOUS
(Not included in Tables 30 or 31)

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
F.	Anvils	40-lb. (for use with forges, field, light), and 1¼ cwt.	
W.1.	Augers, earth ...	6-in. and 8-in.	
W.1.	Bars, boring and jumping, steel, octagonal, chisel end, miners—		
	No. 1, Mk. I. ...	1½ in. wide, 2 ft. 0 in. long	
	No. 2, Mk. I. ...	1⅜ in. ,, 3 ft. 0 in. ,,	
	No. 3, Mk. I. ...	1¼ in. ,, 4 ft. 0 in. ,,	
	No. 4, Mk. I. ...	1½ in. ,, 5 ft. 6 in. ,,	
	No. 5, Mk. I. ...	1 in. ,, 7 ft. 0 in. ,,	
	No. 6, Mk. I. ...	3⅛ in. ,, 2 ft. 6 in. ,,	
	No. 7, Mk. I. ...	3 in. ,, 3 ft. 6 in. ,,	
	No. 8, Mk. I. ...	2⅞ in. ,, 4 ft. 6 in. ,,	
	No. 9, Mk. I. ...	2¾ in. ,, 5 ft. 6 in. ,,	
	No. 10, Mk. I. ...	2⅝ in. ,, 7 ft. 0 in. ,,	
W.1.	Bars, pinching (spike and lever miners).	3 ft. and 4 ft. long.	
E.3.	Blocks, tackle, G.S., cordage, malleable, cast iron, galv.	Single, double, treble, and snatch (and size of cordage).	
E.3.	Blocks, tackle, G.S., wire rope, malleable, cast iron, galv.	—	
W.1.	Blowers	For ventilating mines, etc. Hose and wrenches issued separately.	
W.1.	Baskets, miners, Mk. I.	For raising earth from shafts.	
W.1.	Candlesticks, miners ...	With bottom and side spikes.	
J.	Flarelights, acetylene	Calcium carbide is a R.A.S.C. supply.	
F.	Forges, field	Heavy and light (with detachable handle and blower).	
F.	Hammers, carpenters, claw.	1 lb. 8 oz.	
F.	Hammers, mash ...	—	
F.	,, masons, chisel point.	—	
W.1.	Hammers, miners, boring.	7-lb.	
W.1.	Hammers, miners, sledge.	14-lb.	

TABLE 33—*continued.*

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
F.	Hammers, sledge ...	—	
F.	„ smith's, hand.	3-lb.	
F.	Hammers, stone-breaking.	2-lb., 4-lb., and 6-lb.	
Y.	Jumpers, steel ...	For post holes, 2 ft. 9 in. by 2 in., 27 lb. 10 oz.	
Y.	Ladders, field telegraph, Mk. IV.	16 ft. 6 in. in two lengths.	
W.1.	Ladders, rope, miners'	20, 30 and 50 ft.	
J.	Lamps, acetylene ...	Calcium carbide is a R.A.S.C. supply.	
W.1.	Lamps, miners, A. ...	—	
L.	„ hurricane ...	—	
W.1.	Levels, F.S., Mk. IV....	4-ft., with spirit level.	
J.	Mauls, with helves ...	—	
W.1.	Rods, measuring, 6-ft.	Wood, flat, each foot divided into quarters.	
W.1.	Scrapers, miners ...	6 ft. by ½ in. with 2 in. diameter, scraper each end; 6 ft. by ⅜ in. with 1 in. diameter, scraper each end.	
F.	Spanners, adjustable...	7-in., 11-in., and 15-in.	
V.2.	Tapes, measuring, metallic woven.	50 ft. and 100 ft.	
V.2.	Tapes, measuring, steel.	100-ft.	
W.1.	Tapes, tracing, Mk. I.	50 yd.; 1½ in. white web.	
W.1.	Trucks, miners, Mk. IV.	—	
W.1.	Wedges, miners, Mk. I.	—	
E.3.	Winches, Nos. 1 and 2	Hand power winches, to lift 25 and 50 tons.	
E.3.	Winches, 1-ton ...	—	

TABLE 34.—SANDBAGS, CANVAS

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
H.2.	Hessian, rot-proof ...	5-ft. wide; 120 yds. in roll.	Yards
H.2.	Hessian	28-in. wide; 110 yds. in roll.	„

TABLE 34—*continued.*

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
A.2.	Cloth, union, anti-gas	54-in. wide; 74 yards in roll.	Yards
J.	Covers, waterproof, black, G.S.	Sizes in feet: 30 × 30, 30 × 20, 24 × 18, 20 × 15, 12 × 10.	
N.I.V.	Felt, roofing	3-ft. wide; 25 yards in roll.	Roll
N.I.V.	Sheeting, corrugated, iron.	2 ft. 3 in. wide; in 6-ft., 7-ft. and 9-ft. lengths.	
W.1.	Sandbags	Bales of 220.	Bales

TABLE 35.—CORRUGATED SHELTERS AND IRON SHEETS

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
N.I.V.	Straight sheets, black or painted.	6 ft. to 9 ft. by 2 ft. 2 in., 22 or 24-gauge, 10 sheets to bundle.	Bundles
N.I.V.	Straight sheets, painted black or galvanized.	7 ft. by 2 ft. 2 in., 22-gauge, 10 sheets to bundle.	„
N.I.V.	Curved sheets for bivouac shelter.	9 ft. by 2 ft. 2 in., 18-gauge, bent to 7 ft. radius. Carries one layer of sandbags or equivalent weight. Five sheets to a bundle.	„
N.I.V.	Curved sheets for bivouac shelter.	9 ft. by 2 ft. 2 in., 22-gauge, bent to 9 ft. radius. Will carry no weight. Ten sheets to bundle.	„
N.I.V.	Corrugated steel shelter, large.	17 ft. 9 in. by 9 ft. 6 in. by 6 ft. 2½ in. inside dimensions. Made up of 21 curved plates 7 ft. by 2 ft. 9 in., each with six 5-in. corrugations.	
N.I.V.	Corrugated steel shelter, small.	12 ft. 9 in. by 5 ft. 3 in. by 3 ft. 8 in. inside dimensions. Made up of 10 curved plates 5 ft. 6½ in. by 2 ft. 9 in. each with five 6-in. corrugations.	
N.I.V.	Troughing	6 ft. or 9 ft. long, 3 ft. 3 in. wide.	

TABLE 36.—ROLLED STEEL JOISTS AND RAILS

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
N.I.V.	Joist steel, rolled—		
N.I.V.	12 in. by 5 in. ...	30 lb. a ft. run.	
N.I.V.	10 in. by 4½ in. ...	25 lb. a ft. run.	
N.I.V.	9 in. by 4 in. ...	21 lb. a ft. run.	
N.I.V.	8 in. by 4 in. ...	18 lb. a ft. run.	
N.I.V.	6 in. by 3 in. ...	12 lb. a ft. run.	
W.I.	Joists, steel, Mk. I.—		
	5 in. by 3 in. ...	Length 9 ft., 11 lb. a ft. run.	
W.I.	5 in. by 3 in. clips, Mk. I.	—	
N.I.V.	Rail, steel, bullheaded—		
N.I.V.	40 lb.	Height 3½ in., 13½ lb. a ft. run.	
N.I.V.	60 lb.	Height 4¼ in., 20 lb. a ft. run.	
N.I.V.	80 lb.	Height 5 in., 26⅓ lb. a ft. run.	

TABLE 37.—POSTS AND PICKETS

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
W.I.	Pickets, angle steel, long.	6 ft. long.	
W.I.	Pickets, angle steel, medium.	3 ft. 6 in. long.	
W.I.	Pickets, angle steel, short.	2 ft. long.	
W.I.	Pickets, screw, long	5 ft. 7 in. long, 4 eyes.	
W.I.	,, ,, short...	1 ft. 5¼ in. long, 1 eye.	
N.I.V.	,, brushwood—		
	Short	2 ft. 6 in. long, 1½ in. to 2 in. diameter.	
	Long	5 ft. long, 3 to 4 in. diameter.	
	Gabion	3 ft. 6 in. long.	
	Tracing	1 ft. 6 in. long.	
	Barked	For night work.	
	Unbarked	For day work.	
N.I.V.	Pickets, square—		
	Long	5 ft. long.	
	Short	2 ft. 6 in. long.	
	Tracing	9 in. long.	

TABLE 38.—MATERIALS SUITABLE FOR CONCEALMENT OF FIELD WORKS, BATTERIES, ETC.

1. Fish netting in 30 ft. by 30 ft. squares, or wire netting in rolls 30 ft. by 6 ft., garnished with canvas knots, with or without irregular islands of scrim, mainly for use in open country.

2. Fish netting (30 ft. by 30 ft.) or wire netting (30 ft. by 12 ft.), furnished only with large islands of scrim, for use in broken country. Fish nets (10 ft. by 10 ft.) with raffia.

3. Irregular patches of scrim, with or without bare rolls of wire netting 30 ft. by 6 ft., to be used for supplementing, or actually making up material mentioned in paragraph 2, above, *in situ*.

4. Scrim sheets, 30 ft. long by 6 or 12 ft. wide, for covering spoil, sandbags, etc., or any other light-toned objects under material as in paragraphs 1, 2 or 3 above.

5. Posts 2 in., of varying lengths, pickets and wire, for supporting camouflage.

TABLE 39.—TIMBER (R.E. SUPPLY)

(*Note*.—Timber may either be felled and trimmed on the spot, collected from timber stores in adjacent towns or villages, obtained by dismantling structures containing timber, or demanded from the engineer parks and dumps. The following table gives the ordinary sizes in which timber may be expected to be available.)

Designation (1)	Size (2)	How issued (3)
Planking ...	¾ in. 1 in. 1½ in. 2 in.	In various widths and lengths. Demand by the foot run.
Scantlings ...	3 in. by 3 in. 4 in. by 2 in. 4 in. by 3 in. 4 in. by 4 in. 6 in. by 3 in. 6 in. by 4 in. 6 in. by 6 in. 9 in. by 3 in. 9 in. by 4 in. 9 in. by 6 in. 9 in. by 9 in.	In various lengths. Demand by the foot run, giving a minimum " piece length " for 6 in. by 6 in., 9 in. by 6 in., and 9 in. by 9 in.

TABLE 39—*continued*

Designation (1)	Size (2)	How issued (3)
Baulks ...	10 in. by 10 in. 12 in. by 6 in. 12 in. by 12 in. 14 in. by 12 in. 16 in. by 8 in.	In various lengths. Demand by the piece.
Spars ...	—	In various sizes and lengths. Demand by the piece, specifying length and diameter.
Pit props ...	—	In various sizes and lengths. Demand by number, specifying diameter and length.

TABLE 40.—CORDAGE

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
H.2.	i. Cordage, European hemp, tarred, hawserlaid.	Circumference in inches: 3, 2½, 2, 1½, 1. *Tarred* cordage is weaker, but will stand exposure to weather better than *white*.	Fathom (coils of 113 fms.)
H.2.	ii. Cordage, Italian hemp, white, hawserlaid.	9, 7, 6, 5, 4, 3, 2½, 2, 1½ and 1 in.	
H.2.	iii. Cordage, manila, white, hawserlaid.	A stronger cordage, in the following sizes, circumference in inches: 5, 4, 3½, 3, 2½, 2, 1½, 1.	,,
H.2.	iv. Cordage, coir, hawserlaid.	A coarse, light, elastic cordage, which will float upon water, but has only one-fourth the strength of hemp cordage of same size. Sizes: 7, 6, 5 and 4 in.	,,
H.2.	v. Spun yarn, hemp, tarred.	1 yarn or 3 yarn.	Cwt.
	Do., white.	3 yarn or 5 yarn.	Cwt.
H.2.	vi. Lines, Hambro.		Each.

TABLE 41.—BRIDGING AND BOAT STORES

(*See also* Military Engineering, Vol. III)

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)
E.2.	Anchors, pontoon.	1 cwt.
E.2.	Baulks, shore, end, inner.	
	,, ,, ,, outer.	
	,, ,, ,, F.B.E., inner.	
	,, ,, ,, F.B.E., outer.	
E.2.	Boathooks.	11 ft. 7½ in. long.
E.2.	Boats, folding.	
E.2.	Bolts, hook.	
E.2.	Buoys, anchor.	
E.2.	Chains, racking.	
	,, ,, F.B.E.	
E.2.	Chesses, solid.	
	,, stiffening.	
	,, solid, F.B.E.	
E.2.	Connectors, raft, F.B.E.	
E.2.	Couplings, pontoon, deck.	
	,, ,, side.	
E.2.	Decking, assault bridge.	
E.3.	Drivers, pile, Swiss.	With steel guide bar.
E.2.	Floats, Kapok, assault bridge.	Approx. 6 ft. 6 in, by 1 ft. 9 in. by 9 in.
E.2.	Jackets, life, R.E.	
E.3.	Jacks, lifting and traversing, hydraulic.	30 tons.
	Jacks, lifting and traversing, screw.	6 tons and 12 tons.
	Jacks, lifting, G.S.	
	,, ,, hydraulic, G.S.	7½ tons, 15 tons and 22½ tons.
	,, ,, screw.	1 ton, 5 tons and 8 tons.
E.2.	Joists, compound.	
E.4.	Oars.	Ash, coppered and leathered, 10, 12 and 14-ft.
E.2.	Pins, fixing, assault bridge.	
E.2.	Pontoons, Mk. IV.	Consuta wood.
E.2.	Pumps, pontoon.	
E.2.	Rafts, endloading, F.B.E., decking end.	
	Rafts, endloading, F.B.E. decking, main.	
	Rafts, endloading, F.B.E., legs.	
	,, ,, ,, transoms.	

TABLE 41—*continued*

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)
E.2.	Ribands, cut bay.	
	,, wood.	
	,, wood, F.B.E., long.	
	,, ,, ,, short.	
E.2.	Roadbearers, cut bay.	
	,, steel.	
	,, F.B.E. long, plain.	
	,, ,, ,, button.	
	,, ,, short, plain.	
	,, ,, ,, button.	
E.2.	Rowlocks, Mk. IV, bow.	
	,, ,, ,, clips.	
	,, ,, side or stern.	
	,, ,, ,, ,, clips.	
E.2.	Saddles, pontoon.	
	,, trestle.	
E.3.	Tackles, differential.	5, 10 and 15-cwt. 1, 1½, 2, 3, 4, 5, 6, 8, 10 and 15-tons.
E.2.	Transoms, assault bridge.	
	,, stiffening.	
E.2.	Transoms, F.B.E., shore end.	
	,, ,, stiffening.	
E.2.	Trestles, bridging, Mk. V, feet.	
	,, ,, ,, jacks.	
	,, ,, ,, legs.	
	,, ,, ,, transoms.	
E.2.	Trestles, bridging, F.B.E., Mk. I, jacks.	
	Trestles, bridging, F.B.E., Mk. I, legs.	
	Trestles, bridging, F.B.E., Mk. I, saddles.	
	Trestles, bridging, F.B.E., Mk. I, shoes.	
	Trestles, bridging, F.B.E., Mk. I, struts.	Telescopic.
	Trestles, bridging, F.B.E., Mk. I, transoms.	

TABLE 42.—WIRE AND WIRE ROPE

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)					How issued (4)
E.3.	Rope, galvanized, steel wire.	In coils of 100 fms.					Ft.
E.3.	Sizes, circumference, in.	3	2½	2	1½	1¼	1
	Approx. weight, lb. a fm. Safe load ($9C^2$) cwt.	7 81	4½ 56	2¾ 36	1¾ 20	1 14	¾ 9
E.3.	Rope, wire, 10 tons breaking load.	20 fm. and 40 fm. lengths.					Length
G.2.	Wire, galvanized iron, No. 14 S.W.G.	In 28-lb. and 56-lb. coils.					Coil.
W.1.	Wire, barbed	No. 12½ S.W.G. 130 yds. 28 lb. net a coil. 14 S.W.G. 176 yds. 28 lb. net a coil.					,,
W.1.	Wire, entanglement (French).	One coil = 29 ft. In bundles of 5 coils and approx. 19½ lb. each coil. Staples in boxes containing 300.					,,
	Wire netting	3-ft. wide, in rolls coning 50 yds.					Roll.
W.1.	Expanded metal ...	Sheet 6 ft. 6 in. long by 3 ft. wide. In cases of 20 sheets.					Sheet.

The table below gives the properties, weight, etc., of new iron wire. New steel wire may be taken as twice the strength given, otherwise similar in size, etc. ; galvanized wire is heavier.

Size, S.W.G.	1	2	3	4	5	6	7	8	9	10	11	12	13
Diameter, in.	0·300	0·276	0·252	0·232	0·212	0·192	0·176	0·160	0·144	0·128	0·116	0·104	0·092
Yards a cwt.	155	183	220	260	311	380	452	546	675	854	1040	1293	1653
Lb. a mile...	1268	1073	895	758	633	518	436	369	292	231	190	152	119
Approximate breaking strain, lb.	3804	3219	2685	2274	1899	1554	1308	1080	876	693	570	456	357

Size, S.W.G.	14	15	16	17	18	19	20	21	22	23	24	25	26
Diameter, in.	0·080	0·072	0·064	0·056	0·048	0·040	0·036	0·032	0·028	0·024	0·022	0·020	0·018
Yards a cwt.	2186	2699	3416	4462	6073	8745	10796	13663	17846	24290	28908	34978	43184
Lb. a mile ...	90	73	58	44	32·5	22·5	18·2	14·4	11	8·1	6·8	5·6	4·6
Approximate breaking strain, lb.	270	219	174	132	98	68	55	43	33	24	20	17	14

TABLE 43.—BOLTS, DOGS, NAILS AND SPIKES

Section in Vocab. of of Stores (1)	Designation (2)	Detail (3)	How issued (4)
G.1.	Bolts, with nuts, hexagon head.	Principal stores sizes : length and diam. in inches : 14 × 1 or ¾, 12 × ¾, 8 × ¾, 6 × ⅝ or ½, 5 × ⅜. Other sizes prepared as required.	
N.I.V.	Bolts, drift	¾ in. × 24 in. and ⅝ in. × 20 in.	
E.5.	Dogs, railway and sawyers, Mk. III.	Straight, 18, 15, 12 and 9 in. long, with 9, 7, 6 and 4 in. spikes, respectively.	
G.1.	Nails, iron, spike (quote store No.).	Length, inches : ... ... 10 9 8 7 6 5 Nails in 1 cwt. (approx.) : ... ... 114 155 193 294 430 590 Army Store No. 187 186 185 184 183 182	lb.
G.1.	Nails, wire, iron grooved.	Length, inches : ... 6 5 4 3 2½ 2 1¾ 1½ 1¼ 1 Nails in 1 lb. (approx.) : 14 20 30 52 100 122 200 300 400 800	lb.

TABLE 44.—WATER SUPPLY STORES

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
W.1.	Apparatus, driving tube wells.		
N.I.V.	Bends, elbows, tees, connectors, reducing sockets, cross-pieces, plugs, caps, nipples, back nuts, screwed flanges.	For pipes of sizes as below.	
N.I.V.	Cocks, stop	For 1½ and 1-in. pipes.	
N.I.V.	,, bib	For 1 and ¾-in. pipes.	
W.1.	Engines, petrol, 3 B.H.P.	With drive shaft and pulley for use with water elevators No. 1.	
W.1.	Hose, prepared, canvas, 1¾ in.	In lengths 6, 12 and 20-ft.	Lengths.
W.1.	Hose, canvas, 2-in. bore.	For delivery only in lengths 20, 30, 50 and 100-ft. with "P" Mk. II unions, canvas or leather sleeves and strap, for lift and force, 2-in. semi-rotary, and portable, steam, Nos. 1 and 2 pumps; and for branching from water-pipes generally.	
W.1.	Hose, rubber, 1½-in. bore, delivery or suction, embedded wire.	In 6, 12 and 20-ft. lengths, with "P" Mk. II unions, wired in for use with lift and force, 2-in. semi-rotary, and portable, steam, Nos. 1 and 2 pumps, and "blowers, rotary, Mk. VI."	
W.1.	Machines, pipe grooving and cutting.		
L.	Pails, iron, galvanized.	3 gals.	
F.	Pipe-cutters ...	For sizes of pipe as below.	
N.I.V.	Pipe, wrought iron, galvanized.	In sizes 6, 4, 3, 2, 1½, 1 and ¾-in. internal diameter.	Ft. run.

TABLE 44—*continued*

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
W.1.	Pump, lift and force, Mk. V.	To lift 60-ft., single barrel horizontal gunmetal with handle. "D" caps, Mk. II. to suction inlet and delivery outlet; about 48 ft. suction hose and 30 ft. delivery hose with strainer and two hose wrenches, "P" Mk. II; weight, 88 lb.; with hose strainer, handle and wrenches, 228 lb.	
W.1.	Pumping sets, centrifugal No. 1.	Rees-Roturbo 3,700 gals. an hour, total head 100 ft.	
W.1.	Pumps, portable, steam.	Vertical, Merryweather's, No. 1, for raising 3,000 gals. an hour against 150-ft. head with 15-ft. suction lift.	
	Do.	No. 2, for raising 3,600 gals. an hour against 450-ft. head with 15-ft. suction lift.	
N.I.V.	Tanks, iron, galvanized, rectangular.	In sizes from 20 to 1,000 gals.	
N.I.V.	Tanks, steel, corrugated, galvanized, circular.	25, 50, 100 to 1,000 gals.; with taps and covers.	
J.	Tanks, waterproof, 1,500 gals. open.	16 ft. 9 in. by 16 ft. 9 in. with stores, *see* M.E., Vol. V.	
W.1.	Tools, field, screw-cutting, R.E.		
J.	Troughs, water ...	Canvas 48 gals.	
J.	Troughs, waterproof, 350-gals.	With standards, 10 to a set.	Sets.
N.I.V.	Valves, air, sluice or reflex.	For 4, 6 and 3-in. pipes.	
N.I.V.	Valves, ball, stop or reflex.	For 2-in. pipes.	
N.I.V.	Valves, ball ...	For 1½ and 1-in. pipes.	
W.1.	Water elevators, No. 1.	Aquatole type capable of lifting 3,000 gals. an hour.	
F.	Wrenches, pipe, chain.	For sizes of pipe as above.	

TABLE 45.—DEMOLITION STORES

Section in Vocab. of Stores (1)	Designation (2)	Detail (3)	How issued (4)
		Bulk Explosives	
N.I.V.	Ammonal	Packed in 25-lb. and 50-lb. waterproof tins. Dimensions :— 25-lb. tin, 9 by 9¼ by 9 in. 50-lb. tin, 11⅞ by 10¼ by 12¼ in.	Tins.
N.I.V.	Dynamite Blasting gelatine.	Not an ordnance store, but, as a rule, obtainable from this source ; manufactured in various grades and strengths, usually in 2-oz. cartridges packed in boxes of 5 lb. and 50 lb.	Lbs.
T.1.	Guncotton, wet, slabs, field, 1 lb.	Slabs 6 by 3 by 1⅛ in., one perforation for 1-oz. primer ; packed in waterproof boxes containing fourteen slabs.	Lbs.
T.1.	Gunpowder.		
		Auxiliary Explosives, etc.	
T.2.	Bags, guncotton, waterproof.	Rubber-proofed fabric, 25, 5, and 2 lb.	
W.2.	Cable, electric, E1, Mk. II.	For electric firing ; weight 5 to 7 lb. for each 100 yds.	Yards.
N.I.V.	Caps, copper, blasting. (Commercial caps.)	The commercial equivalent of the No. 8 detonator ; manufactured in ten standard strengths, sizes 1 to 10.	
T.1.	Detonators, No. 8, Mk. VII.	For use with safety and with detonating fuze ; packed in tins of 25.	
T.1.	Detonators, electric, No. 9, Mk. IV.	For use in electric firing ; packed in tins containing 25 detonators and a rectifier.	
W.2.	Exploders, dynamo	For firing charges electrically ; size 13⅛ by 8⅛ by 6¼ in. ; weight 27 lb.	Each.
T.1.	Fuze, safety, No. 11, Mk. I.	In tin cylinders containing 48 ft.	
T.1.	Fuze, instantaneous, detonating.	Wound on reels.	Yards.

TABLE 45—*continued*

Section in Vocab. of Stores (1)	Designation. (2)	Detail. (3)	How issued. (4)
T.1.	Fuzes, electric, No. 14, Mk. IV.	For use with low explosives fired electrically ; packed in tins of 25.	
T.1.	Guncotton, dry, primers, field, 1-oz., Mk. I.	Packed in sealed tin cylinders containing 10 primers.	
T.1.	Igniters, safety fuze, percussion, Mk. II.		
Q.1.	Matches, fuzee, safety.	25 in a box.	
U.	Pans, warming dynamite, Mk. I.		
T.2.	Rectifiers, guncotton primers, Mk. VI.		
		Testing Apparatus, Electric Firing	
W.2.	Boxes, testing and jointing, filled	Tin box in leather cover ; size 14 by 8 by 5¼ in. ; weight 12 lb. 3 oz. ; the contents are as follows :— For testing :— 1 box of resistance coils (100 ohms). 1 "Q" and "I" detector. 1 box, safety test, cell S, Mk. I. 3 dwts. of iridio-platinum wire on 8 metal reels. 1 chamois leather. 1 box of plate powder. For jointing :— 1 pair 5-in. sidecutting pliers. 2 3-oz. tubes of india-rubber solution. 4 2-oz. cylinders of india-rubber tape. ½ lb. of cotton waste.	

4. Notes on man-power

For man-power constants, *see* Sec. 57, 2.

APPENDIX II

ORGANIZATION OF WORK

1. Example

1. The principles and organization are dealt with in the Manual of Field Engineering, Vol. I (all Arms).

The following example is intended to illustrate :—

i. The method of working out a single task.
ii. How to make out a work table and working party demand.
iii. How to make out a stores list.

2. The task is to dig a platoon locality, *see* Plate **9**, consisting of four section posts joined together with fire trenches of a trace similar to the posts—and a C.T. from front to rear, and to revet the whole.

The example shows the calculations for a typical piece of work of each kind ; the figures for the remainder of the work, though not calculated here in detail, are shown in tabular form. It must be clearly understood that the example shown is only one type of locality. There are many other variations of trace possible which will be used according to the ground. A traversed trace affords better protection but takes longer to construct. It will, however, frequently be used. The *wiring* of the locality will probably take place at the same time, but is not included in this example. Normally, a locality of this type would probably be developed from rifle pits or section posts unless it were part of some defensive work in a back area, which this is assumed to be.

i. *Assumptions.*

(*a*) There are twelve hours of daylight.
(*b*) Infantry working parties are available, as required, but for four-hour shifts only.
(*c*) Stores have to be carried half a mile.
(*d*) About two sections of a Fd. Coy. are available for revetment for one day only and a few men for supervision of technical details on the other days.
(*e*) The soil is average loam.

ii. *Calculations.*—For details of tasks, *see* Figs. **4** and **5.** All other references to Plate **9.**

(*a*) *Excavation.*—

POST NO. 1 TO POST NO. 2 (INCL.)

1st Task.

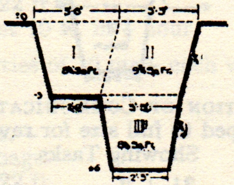


FIG. 4.—SECTION OF FIRE TRENCH
(Developed to full size for revetment)
Showing Tasks

Sectional area is $\frac{3\frac{1}{2} + 2}{2} \times 3 = 2\frac{3}{4} \times 3 = 8\frac{1}{4}$ sq. ft.

Length is 222 ft.
Allowing 6 ft. along the line for each man.
Number of men required is $\frac{222}{6} = 37$.

Each man will have to dig $8\frac{1}{4} \times 6 = 49\frac{1}{2}$ cu. ft. in the 4-hours' task. This is a fairly light task, but as the trench is laid out in multiples of 3 ft. it will be found simpler to keep to 6 ft. and avoid difficulties at corners. The tasks as set should allow ample time for change over between shifts.

2nd Task.

Sectional area is $\frac{3\frac{1}{4} + 3\frac{1}{4}}{2} \times 3 = 3\frac{1}{4} \times 3 = 9\frac{3}{4}$ sq. ft.

Allowing 6 ft. along the line for each man, his task will be $9\frac{3}{4} \times 6 = 58\frac{1}{2}$ cu. ft.
Number of men required will be 37 as before.

3rd Task.

Sectional area is $\frac{3\frac{1}{4} + 2\frac{1}{4}}{2} \times 3 = 2\frac{3}{4} \times 3 = 8\frac{1}{4}$ sq. ft.,

or the same as the first task.

50 per cent. men must be allowed for shovelling as the trench is over 4 ft. deep. Therefore number of men required is $37 + \frac{37}{2} =$ say, 56 men.

COMMUNICATION TRENCH

1st Task.

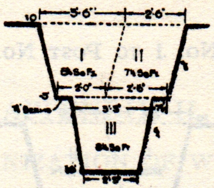


FIG. 5.—SECTION OF COMMUNICATION TRENCH (Developed to full size for revetment) Showing Tasks

Sectional area is $\frac{3\frac{1}{2} + 2}{2} \times 3 = 8\frac{1}{4}$ sq. ft.

Length is 150 ft.

In this case allow 7 ft. along the line to give a full task.

Task will be $8\frac{1}{4} \times 7 = 57\frac{3}{4}$ cu. ft.

Number of men required is $\frac{150}{7} = 22$.

2nd Task.

Sectional area is $\frac{2\frac{1}{2} + 2\frac{1}{2}}{2} \times 3 = 2\frac{1}{2} \times 3 = 7\frac{1}{2}$ sq. ft.

Try 8 ft. along the line.

Then task is $7\frac{1}{2} \times 8 = 60$ cu. ft.

Number of men required is $\frac{150}{8} = 19$.

3rd Task.

Sectional area is $\frac{3\frac{1}{4} + 2\frac{1}{4}}{2} \times 3 = 2\frac{3}{4} \times 3 = 8\frac{1}{4}$ sq. ft.

Therefore number of men required is the same as for the first task + 50 per cent. shovellers.

I.e. 22 + 11 = 33.

Digging other posts is calculated in a similar manner.

NOTE.—If there are plenty of men available it is often advantageous to dig the first and second tasks at the same time in a case of this sort. Each man then gets 6 ft. 9 in. or 6 ft. width and 3 ft. or 3 ft. 6 in. length in fire trench and C.T. respectively.

(*b*) *Revetment.*—

POST NO. 1 TO POST NO. 2 (INCL.)

i. **Passage trench.**—

Use X.P.M. panels and "A" frames.

Length is 222 ft. and there are 8 corners.

7 men revet 10 ft. in ½ hour.

Suppose we start in four places, then each party will have to do 56 ft. and two corners.

A party of 7 men revet 56 ft. in $\frac{56}{20}$ hours $\doteqdot$ 2 hours 48 mins., add 15 mins. each corner, then total time = 3 hours 18 mins. for 28 men.

ii. **Interior slope.**—

Use X.P.M. panels and pickets.

Length is 222 ft.

10 men revet 10 ft. in ½ hour.

Using 4 parties of 10 men, each will do 56 ft. in $\frac{56}{20}$, say 3 hours.

iii. **Elbow rest.**—

Using sandbags.

Length is 222 ft.

Allowing 6 bags for 20-in. length to do elbow rest and parapet.

Five men fill and lay 60 bags in 1 hour.

Number of bags required is $\frac{222 \times 12 \times 6}{20} = 799{\cdot}2$, say 800.

5 men would take $\frac{800}{60} = 13\frac{1}{3}$ hours.

But we want to finish in 3 hours if possible, so start in 5 places.

Then the number of hours taken by 25 men is $\frac{13\frac{1}{3}}{5} = 2\frac{2}{3}$.

Revetment of post 3 to 4 (incl.) is calculated in a similar manner.

iv. **Communication trench.**—

Using X.P.M. panels and "A" frames, passage trench only.

Length is 150 ft.—4 corners.

7 men revet 10 ft. in ½ hour.

Therefore 7 men revet 150 ft. in 7½ hours.

Starting in 3 places 21 men would take 2½ hours.

Allowing 15 mins. for each corner they will take 3 hours

POST 1 TO POST 2 (INCL.)

v. **Trench boarding.**—

Length is 222 ft.—8 corners.

3 men do 10 ft. in 10 mins.

Allow 10 mins. extra for each corner.

3 men do 222 ft. in 222 mins., or starting in 2 places, 6 men will take 111 mins. = 1 hour 50 mins. + 40 mins. each party for corners, or a total of 2½ hours.

Remainder of locality calculated in a similar manner.

EXCAVATION SUMMARY

Serial No.	Place	Task	Secl. Area	Length ft.	Men	Time hours	Remarks
1	Posts 1–2 incl.	First	8¼	222	37	4	
2	C.T. front to rear.	First	8¼	150	22	4	
3	Posts 3–4 incl.	First	8¼	216	36	4	
4	Posts 1–2 incl.	Second	9¾	222	37	4	
5	C.T. front to rear	Second	7½	150	19	4	
6	Posts 3–4 incl.	Second	9¾	216	36	4	
7	Posts 1–2 incl.	Third	8¼	222	56	4	Includes 19 (50 per cent.) shovellers.
8	C.T. front to rear.	Third	8¼	150	33	4	Includes 11 (50 per cent.) shovellers.
9	Posts 3–4 incl.	Third	8¼	216	54	4	Includes 18 (50 per cent.) shovellers.

REVETTING SUMMARY

Serial No.	Place	Task	Material	Length ft.	Men	Time	Remarks
11	Posts 1–2 incl.	Passage trench.	X.P.M. panels and "A" frames	222	28	3¼	Starting in 4 places.
12	C.T. front to rear.	,,	,,	150	21	3	Starting in 3 places.
13	Posts 3–4 incl.	,,	,,	216	28	3¼	Starting in 4 places.
14	Posts 1–2 incl.	Interior slope	X.P.M. panels and pickets	222	40	3	,, ,,
15	Posts 3–4 incl.	,,	,,	216	40	3	,, ,,
16	Posts 1–2 incl.	Elbow rests	Sandbags	222	25	2⅔	Starting in 5 places.
17	Posts 3–4 incl.	,,	,,	216	25	2⅚	,, ,,
18	Posts 1–2 incl.	Trenchboards		222	6	2½	Starting in 2 places.
19	C.T. front to rear.	,,		150	3	2½	,, ,,
20	Posts 3–4 incl.	,,		216	6	2½	,, ,,

REVETTING MATERIAL

Place	Task	A frames	Special corner "A" frames	X.P.M. panels	Trench boards	Pickets		Sand-bags	Wire S.W.G. ft.	Remarks
						5 ft.	2 ft 6 in.			
Post No. 1 to Post No. 2 (incl.).	Passage trench.	76	8	74	37	—	—	—	—	Wire S.W.G. 8 strands for each picket, 10 ft. per strand.
	Interior slope.	—	—	37	—	79	79	—	6,320	
	Elbow rest	—	—	—	—	—	—	800	—	
Post No. 3 to Post No. 4 (incl.).	Passage trench.	74	8	72	—	—	—	—	—	
	Interior slope.	—	—	36	36	76	76	—	6,080	
	Elbow rest.	—	—	—	—	—	—	778	—	
C.T. front to rear	Passage trench.	52	4	50	25	—	—	—	—	
TOTAL		202	20	269	98	155	155	1,578	12,400	
Add 5 per cent. approx. damages, losses, etc. ...		10	2	13	7	10	10	—	—	
GRAND TOTAL		212	22	282	105	165	165	7 bales	2 cwt.	

WORK TABLE

[To face p. 379.

1	2	3	4	5	6	7	8	Allotment of labour																											
Serial No.	Task	Sub-divisions of task	Quantity cu. ft.	Men		Hours	Man Hours	First day												Second day												Tools		Materials	Remarks
								Shift 1				Shift 2				Shift 3									Lunch hour										
				R.E.	Inf.			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	Picks	Shovels		
1	Excavation 1st task.	Post 1–2 incl.	1,831⅓	1	37	4	148	37	37	37	37																					37	37		
2		CT front to rear.	1,237½		37	4	88	22	22	22	22																					22	22		
3		Post 3–4 incl.	1,782		37	4	144	36	36	36	36																					36	36		
4	Excavation 2nd task.	Post 1–2 incl.	2,174	1	37	4	148					37	37	37	37																	37	37		
5		CT front to rear.	1,125		19	4	76					19	19	19	19																	19	19		R.E. on first day are guides. Not included in shift details.
6		Post 3–4 incl.	2,092		36	4	144					36	36	36	36																	36	36		
7	Excavation 3rd task.	Post 1–2 incl.	1,831⅓	1	56	4	224									56	56	56	56													37	56		
8		CT front to rear.	1,237½		33	4	132									33	33	33	33													22	33		
9		Post 3–4 incl.	1,782		54	4	216									54	54	54	54													36	54		
10	Carrying stores.		727 man-loads	1	50	8	400					50	50	50	50	50	50	50	50													—	—		
11	Revetting passage trench.	Post 1–2 incl.	222′	28	—	3	84													28	28	28												*See* separate stores list.	The odd ½ hour lost on passage trench will be made up by over allowance on trench boarding. Work to nearest hour.
12		CT front to rear.	150′	21	—	3	63													21	21	21													
13		Post 3–4 incl.	216′	28	—	3	84													28	28	28													
14	Do. Interior slope.	Post 1–2 incl.	222′	40	—	3	120																40	40	—	40									
15		Post 3–4 incl.	216′	40	—	3	120																40	40	—	40									
16	Do. Elbow rest.	Post 1–2 incl.	222′	25	—	3	75																				25	25	25						Approx. 2 secs. R.E. employed all second day.
17		Post 3–4 incl.	216′	25	—	3	75																				25	25	25						
18	Trench boarding.	Post 1–2 incl.	222′	6	—	2	12																				6	6	6						No spare inf. allowed for as work is not under fire.
19		CT front to rear.	150′	3	—	2½	7½																				3	3	3						
20		Post 3–4 incl.	216′	6	—	2	12																				6	6	6						
							2,381																												
			Spare																	3	3	3	—	—	—	—	15	15	15						
				TOTALS R.E.				6	6	6	6	10	10	10	10	10	10	10	10	80	80	80	80	80		80	80	80	80						
				Inf.				95	95	95	95	142	142	142	142	193	193	193	193																

[*To face p.* 379.

1	2	3	4	5	6		
Serial No.	Task	Sub-divisions of task	Quantity cu. ft.	Men		H	Remarks
				R.E.	Inf.		
1	Excavation 1st task.	Post 1–2 incl.	1,831½	1	37		
2		CT front to rear.	1,237½		37		
3		Post 3–4 incl.	1,782		37		
4	Excavation 2nd task.	Post 1–2 incl.	2,174	1	37		R.E. on first day are guides. Not included in shift details.
5		CT front to rear.	1,125		19		
6		Post 3–4 incl.	2,092		36		
7	Excavation 3rd task.	Post 1–2 incl.	1,831½	1	56		
8		CT front to rear.	1,237½		33		
9		Post 3–4 incl.	1,782		54		
10	Carrying stores.		727 man-loads	1	50		
11	Revetting passage trench.	Post 1–2 incl.	222′	28	—		The odd ½ hour lost on passage trench will be made up by over allowance on trench boarding. Work to nearest hour.
12		CT front to rear.	150′	21	—		
13		Post 3–4 incl.	216′	28	—		
14	Do. Interior slope.	Post 1–2 incl.	222′	40	—		
15		Post 3–4 incl.	216′	40	—		
16	Do. Elbow rest.	Post 1–2 incl.	222′	25	—		Approx. 2 secs. R.E. employed all second day.
17		Post 3–4 incl.	216′	25	—		
18	Trench boarding.	Post 1–2 incl.	222′	6	—		No spare inf. allowed for as work is not under fire.
19		CT front to rear.	150′	3	—		
20		Post 3–4 incl.	216′	6	—		
			Spare				
				Totals R.E.			
				Inf.			

Carrying Party for Revetting Material

Material (1)	No. (2)	Man loads (3)
"A" frames	212	212
Special "A" frames ...	22	22
X.P.M. panels	292	292
Trench boards	105	105
Pickets—5-ft.	165	41
Pickets—2-ft. 6-in. ...	165	20
Sandbags	7 bales (1,750)	27
Wire 14 S.W.G.	2 cwts.	8
	Total	727

Assuming men carry stores ½ mile—rate 2 m.p.h.

Then 1 journey takes 30 minutes.

Assuming a man does 8 journeys a 4-hour shift and there are 2 shifts.

The number of men required $= \dfrac{727}{8 \times 2} = 46$ for 2 four-hour shifts, say, 50 men.

2. The work table

The work table is designed to simplify the calculation of labour for an engineering operation.

First, write down in Cols. 2 and 3 of the work table the various subdivisions of the work in the natural order in which they will take place. In Col. 4 put the quantity to be done. In Col. 8 fill in the man-hours required. This can be obtained from tables in this book or estimated from experience. In Cols. 5 and 6 fill in the most suitable size of party having regard to the number of men available and the number that can conveniently work at one time. This is obtained by dividing the number of men into the figure placed in Col. 8. Neglect half-hours or equalize them between tasks for simplicity. It will be evident from what has been put down in Cols. 2 and 3 when the tasks can commence and when stores must arrive, etc.

Divide the columns under allotment of labour into days and shifts and hours as convenient and according to the number of working hours available. Do not forget that if sappers are to work long shifts they will require food during the day.

Then fill in the number of men to work at each task in each hour. It may be necessary at this stage to make one or two trials because it will usually be necessary to keep the number of men in any one shift the same during the shift. Further, the number of men available may be limited. This form of table makes it easy to work this out without keeping figures in the head. There is a line at the bottom for spare men. It will usually be impossible to make the columns add up exactly to the number of men available for each shift, but the number of men shown spare should obviously be very few. In some jobs it may be advisable to allow spare men purposely for replacing casualties or for unforeseen work.

When infantry working parties are employed it will usually be necessary to have a few engineer N.C.Os. or sappers for technical supervision, measuring tasks, etc. These will be shown in Col. 5, but, as they are not working on the task, it is only confusing to show them in the shift columns. Show them in the totals line and make a note in the remarks column.

Finally tools and stores can be entered in the appropriate columns, but often it will be simpler to refer to a list of tools or materials in this manner —" *see* Item 1, stores list."

3. The working party demand

This is easily compiled from the work table. If the work is to last several days it would only be made out for a day at a time so that any necessary amendments can be made if the work has not proceeded exactly according to plan. In such cases a progress record on the lines of the work table is kept, showing what has been actually achieved.

WORKING PARTY DEMAND

Serial No.	Date	No. of working men	Unit providing working party (A)	Rendezvous		Guides	Nature of work (Unit task where applicable)	Tools to be supplied by unit	Estimated time of completion	O. i/c work	Remarks
				Place	Time						
1	1.7.35	95		Suitable rendezvous map reference	0700	Spr. Smith	Excavation of first task. Platoon post at ——.	95 picks. 95 shovels.	1100	Lt. Green, R.E.	
2	1.7.35	92		"	1100	"	Excavation of second task. Platoon post at ——.	92 picks. 92 shovels.	1500	"	
3	1.7.35	50		"	1100	Spr. Jones	Carrying revetting stores for above.	Nil.	1500	"	
4	1.7.35	143		"	1500	Spr. Brown	Excavation of 3rd task.	95 picks. 143 shovels	1900	"	
5	1.7.35	50		"	1500	Spr. Jones	Carrying revetting stores for above.	Nil.	1900	"	

(A) To be filled in by the formations ordering the working parties

To H.Q. .... Inf. Bde. (Formation).
From..(Signature).
Major, R.E. (Rank).
O.C. .... Fd. Coy. R.E. (Appointment).
30.6.35 (Date).

APPENDIX III

EARTHWORK

1. Notes on tasks

A cubic yard an hour is the usual task from unskilled diggers in easy soil, or 100 cu. ft. in four hours, throwing a maximum horizontal distance of 12 ft., and a vertical lift not exceeding 4 ft.

The above is, however, for easy soil, and unless a soldier has had considerable practice in digging, it will be found that if in ordinary soil he does 60 cu. ft. at first in four hours, it is as much as one can generally get on an average. After a little practice he ought to be able to do 100 cu. ft. in four hours. Sappers can do a yard and half an hour; they should do 30 per cent. more work than infantry in a given time—four hours.

In very stiff soil, gravel, or clay, half-tasks should be estimated for.

In estimates for working parties in ordinary unknown soil 120 cu. ft. in six hours, or 20 cu. ft. an hour, a man, is fair. Much depends on the health of the working party, the nature of their tools, and their discipline. With the light infantry tools only half the above tasks can be expected.

2. Examples of tasks for various classes of labour

The following table shows the tasks for labour worked on defences in France, at excavation of trenches under the best conditions, *i.e.* good weather, work in daylight, no interference from the enemy. Where these conditions do not apply tasks must be varied accordingly.

First task applies to work in trenches not more than 3-ft. deep.

Second task applies to work in trenches between 3 and 6 ft. deep.

In each case the task is a full day's work.

Classification of soil :—

Grade I.	Hard chalk. with flint etc.	Stiff clay or gravel,	Requiring considerable pick work.
Grade II.	Medium earth. containing gravel, etc.	Earth loose	Requiring very little pick work.
Grade III.	Sand.	Soft earth, etc.	Entirely shovel work.

TABLE 46

	1st Task			2nd Task		
	Soil					
	Grade I	Grade II	Grade III	Grade I	Grade II	Grade III
	f.c.	f.c.	f.c.	f.c.	f.c.	f.c.
Chinese labour companies.	160	200	250	120	160	190
British labour companies.	120	160	190	90	125	150
Reinforcements ...	80	100	120	65	80	100
Infantry	40	50	60	35	40	50

Tasks may be reduced when parties are necessarily more than half an hour's journey from the work.

APPENDIX IV

BRIDGING AND ACCESSORIES

TABLE 47.—STRESSES IN DERRICKS, SHEERS AND GYNS

Stresses are given in terms of the weight to be lifted; allowance has been made for the weight of tackles and fittings.

In the case of the swinging derrick, it is assumed that the lay-out is similar to that shown in Plate **84,** the length of the upright spar and the swinging arm are about equal and the angle between them not greater than 75 degrees.

Standing derrick

Spar	2·0W
Guys taking the weight ...	0·7W
Other guys	0·3W

Gyn

Spar with leading block ...	0·6W
Other spars	0·4W

Sheers

Leg with leading block ...	1·2W
Other leg	1·0W
Guys taking the weight ...	0·7W
Other guys	0·3W

Swinging derrick

Upright spar	2·2W
Swinging arm (total) ...	1·4W
Struts, each	0·5W
Connecting tackle	1·6W
Guys taking the weight ...	1·25W
Other guys	0·3W

This table gives the approximate maximum stresses for average conditions; whenever possible the stresses should be determined graphically.

TABLE 48.—SIZE OF SPARS AND BAULKS FOR DERRICKS, SHEERS AND GYNS

Mean diameter of spar in inches	Length of spar in feet from point of attachment of main tackle to the ground														Size of equiva-lent square baulk in inches
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
6	3·4	1·8	0·9	0·4	—	—	—	—	—	—	—	—	—	—	5·0
7	5·4	2·6	1·9	1·0	0·4	—	—	—	—	—	—	—	—	—	5·8
8	8·2	5·1	3·3	2·0	1·1	0·4	—	—	—	—	—	—	—	—	6·7
9	11·8	7·6	5·1	3·4	2·1	1·2	0·5	—	—	—	—	—	—	—	7·5
10	15·9	10·4	7·3	5·1	3·5	2·3	1·3	0·5	—	—	—	—	—	—	8·3
11	20·8	14·0	10·3	7·2	5·3	3·6	2·4	1·3	0·4	—	—	—	—	—	9·2
12	26·4	18·6	13·5	10·0	7·4	5·4	3·8	2·5	1·4	0·5	—	—	—	—	10·0
13	32·9	22·9	17·6	12·9	10·1	7·4	5·6	3·9	2·7	1·5	0·6	—	—	—	10·8
14	40·8	29·9	21·5	16·6	12·9	10·0	7·7	5·8	4·2	2·6	1·5	0·5	—	—	11·7
15	46·7	36·3	27·4	21·1	16·4	12·8	10·4	7·9	5·9	4·2	2·8	1·7	0·6	—	12·5
16	56·9	41·3	32·9	25·2	20·5	16·0	13·1	10·0	8·0	5·9	4·4	2·8	1·7	0·5	13·3

Safe load in tons.

TABLE 49.—TACKLES

(Ref. Sec. 56)

(A) Cordage tackles

RUNNER TACKLES
Maximum safe load in cwt. $[f = \frac{1}{10}]$

Combination of tackles	$P = C^2$ cwt.					$P = 2C^2$ cwt.				
	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0/1	1·8	4·1	7·3	11·4	16·4	3·6	8·2	14·5	22·8	32·8
1/1	2·5	5·6	10·0	15·6	22·5	5·0	11·2	20·0	31·2	45·0
2/1	3·1	6·9	12·3	19·3	27·6	6·2	13·8	24·6	38·5	55·2
2/2	3·6	8·0	14·3	22·4	32·2	7·2	16·1	28·6	44·8	64·4
3/2	4·0	9·0	16·0	25·0	36·0	8·0	18·0	32·0	50·0	72·0
3/3	4·4	9·8	17·5	27·4	39·4	8·8	19·7	35·0	54·8	78·8
	Load on anchorage in cwt.					= W − P.				
0/1	0·8	1·8	3·3	5·1	7·4	1·6	3·7	6·5	10·3	14·8
1/1	1·5	3·4	6·0	9·4	13·5	3·0	6·7	12·0	18·7	27·0
2/1	2·1	4·7	8·3	13·0	18·6	4·2	9·3	16·6	26·0	37·2
2/2	2·6	5·8	12·1	16·2	23·2	5·2	11·6	20·6	32·3	46·4
3/2	3·0	6·7	12·0	18·7	27·0	6·0	13·5	24·0	37·5	54·0
3/3	3·4	7·6	13·5	21·1	30·4	6·8	15·2	27·0	42·3	60·8

LIFTING TACKLES
Maximum safe load in cwt. $[f = \frac{1}{10}]$
Note.—Friction loss in leading block is included.

Combination of tackles	$P = C^2$ cwt.					$P = 2C^2$ cwt.				
	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1/1	1·5	3·5	6·2	9·6	13·8	3·1	6·9	12·3	19·2	27·7
2/1	2·1	4·8	8·6	13·4	19·3	4·3	9·6	17·1	26·8	38·6
2/2	2·7	6·0	10·7	16·7	24·0	5·3	12·0	21·3	33·3	48·0
3/2	3·1	7·0	12·5	19·5	28·1	6·2	14·0	25·0	39·0	56·2
3/3	3·5	7·9	14·1	22·0	31·8	7·0	15·9	28·2	44·1	63·6
	Load on anchorage in cwt.					= W + P.				
1/1	2·5	5·7	10·2	15·9	22·8	5·1	11·4	20·3	31·7	45·7
2/1	3·1	7·1	12·6	19·6	28·3	6·3	14·1	25·1	39·3	56·6
2/2	3·7	8·2	14·7	22·9	33·0	7·3	16·5	29·3	45·8	66·0
3/2	4·1	9·3	16·5	25·8	37·1	8·2	18·5	33·0	51·5	74·2
3/3	4·5	10·2	18·1	28·3	40·8	9·0	20·4	36·2	56·6	81·6

(B) S.W.R. runner tackles

Maximum safe load in tons $[f = \frac{1}{10}]$

Combination of tackles	$P = 9C^2$ cwt.					$P = 10C^2$ cwt.					$P = 11C^2$ cwt.					$P = 12C^2$ cwt.				
	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
0/1	0·8	1·8	3·3	5·1	7·4	0·9	2·0	3·6	5·7	8·2	1·0	2·2	4·0	6·3	9·0	1·1	2·4	4·3	6·8	9·8
1/1	1·1	2·5	4·5	7·0	10·1	1·2	2·8	5·0	7·8	11·2	1·3	3·1	5·5	8·6	12·3	1·5	3·4	6·0	9·4	13·4
2/1	1·4	3·1	5·5	8·7	12·5	1·5	3·5	6·1	9·6	13·9	1·7	3·8	6·8	10·6	15·2	1·8	4·2	7·3	11·5	16·7
2/2	1·6	3·6	6·4	10·0	14·5	1·8	4·0	7·1	11·2	16·1	2·0	4·4	7·8	12·3	17·7	2·1	4·8	8·5	13·4	19·3
3/2	1·8	4·0	7·2	11·2	16·2	2·0	4·5	8·0	12·5	18·0	2·2	4·9	8·8	13·7	19·8	2·4	5·4	9·6	15·0	21·6
3/3	2·0	4·4	7·9	12·4	17·7	2·2	4·9	8·7	13·7	19·7	2·4	5·4	9·6	15·1	21·7	2·6	5·9	10·5	16·5	23·6
						Load on anchorage					*in tons* = W − P									
0/1	0·4	0·8	1·5	2·3	3·3	0·4	0·9	1·6	2·6	3·7	0·5	1·0	1·8	2·9	4·1	0·5	1·1	1·9	3·1	4·4
1/1	0·7	1·5	2·7	4·2	6·1	0·7	1·7	3·0	4·7	6·7	0·8	1·9	3·3	5·2	7·4	0·8	2·1	3·6	5·6	8·0
2/1	0·9	2·1	3·7	5·8	8·4	1·0	2·4	4·1	6·5	9·4	1·1	2·6	4·5	7·2	10·3	1·2	2·9	4·9	7·8	11·3
2/2	1·2	2·6	4·6	7·2	10·4	1·3	2·9	5·1	8·1	11·6	1·4	3·2	5·6	8·9	12·8	1·5	3·5	6·1	9·7	13·9
3/2	1·4	3·0	5·4	8·4	12·2	1·5	3·4	6·0	9·4	13·5	1·7	3·7	6·6	10·3	14·9	1·8	4·1	7·2	11·3	16·2
3/3	1·6	3·4	6·1	9·6	13·6	1·7	3·8	6·7	10·6	15·2	1·9	4·2	7·4	11·7	16·8	2·0	4·6	8·1	12·8	18·2

(C) S.W.R. lifting tackles

Maximum safe load in tons [$f = \frac{1}{10}$]

Friction loss in leading block is included.

Combination of tackles	P = 9C² cwt.					P = 10C² cwt.					P = 11C² cwt.					P = 12C² cwt.				
	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″	1″	1½″	2″	2½″	3″
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1/1	0·7	1·6	2·8	4·3	6·2	0·8	1·7	3·1	4·8	6·9	0·8	1·9	3·4	5·3	7·6	0·9	2·1	3·7	5·8	8·3
2/1	1·0	2·2	3·9	6·0	8·7	1·1	2·4	4·3	6·7	9·6	1·2	2·6	4·7	7·4	10·6	1·3	2·9	5·2	8·1	11·4
2/2	1·2	2·7	4·8	7·5	10·8	1·3	3·0	5·3	8·3	12·0	1·5	3·3	5·9	9·2	13·2	1·6	3·6	6·4	10·0	14·4
3/2	1·4	3·2	5·6	8·8	12·6	1·6	3·5	6·2	9·8	14·0	1·7	3·9	6·9	10·8	15·5	1·9	4·2	7·5	11·8	16·9
3/3	1·6	3·6	6·3	9·9	14·3	1·8	4·0	7·1	11·1	15·9	1·9	4·4	7·8	12·2	17·4	2·1	4·8	8·5	13·3	19·0
Load on anchorage in tons = W + P																				
1/1	1·1	2·6	4·6	7·2	10·3	1·2	2·7	4·9	7·6	11·0	1·3	2·9	5·2	8·1	11·7	1·4	3·1	5·5	8·6	12·4
2/1	1·4	3·2	5·7	8·9	12·7	1·6	3·4	6·1	9·5	13·7	1·6	3·6	6·5	10·2	14·6	1·7	3·9	7·0	10·9	15·5
2/2	1·6	3·7	6·6	10·3	14·8	1·8	4·0	7·1	11·2	16·0	1·9	4·3	7·7	12·0	17·2	2·1	4·6	8·2	12·8	18·5
3/2	1·9	4·2	7·4	11·6	16·7	2·0	4·5	8·0	12·6	18·1	2·2	4·9	8·7	13·6	19·5	2·3	5·2	9·3	14·6	20·9
3/3	2·0	4·6	8·1	12·8	18·3	2·2	5·0	8·9	13·8	19·9	2·4	5·4	9·6	15·0	21·5	2·6	5·8	10·3	16·1	23·1

TABLE 50.—FORMULAE USED IN CONNECTION WITH ROPES AND TACKLES

(*Ref.* Chapters XI and XIII)

Serial No. (1)	Formula (2)	Application (3)	Reference (4)	
			Sec.	Para.
1	Weight of cordage $0·15\,C^2$ lb. a fm.	Average weight of cordage.	52	3
2	Weight of S.W.R. C^2 lb. a fm.	Approximate weight of S.W.R.	54	4
3	$W = C^2$ to $2C^2$ cwt.	Safe load on cordage	51	5
4	$W = 9C^2$ to $12C^2$ cwt.	Safe load on S.W.R.	53	4
5	Safe load = $\frac{2}{3}$ of calculated load.	For cordage or S.W.R. if taken round any sharp bend.	51 53	5 4
6	Safe stress = $\frac{4}{5}$ of calculated stress.	For cordage lashings of more than 4 returns.	51	5
7	Safe stress = $\frac{3}{5}$ of calculated stress.	For S.W.R. lashings of more than 2 returns.	53	4
8	Diameter of sheaves of a block should be 6 times circumference of S.W.R.	Selection of S.W.R. blocks.	53 55	2 1
9	Diameter of anchorage should not be less than 4 times circumference of S.W.R.	Designing anchorages; they should be as large as possible.	53	2
10	Safe load in tons = $\frac{1}{10}$ (number of eighths of an inch in the diameter of iron)^2.	Approximate formula for chains, links, rings, and shackles.	54 54	2 3, v
11	Pull in each arm of a sling = $1·15W$.	For all slings when angle between legs is 60 degrees.	54	3
12	Pull in each arm of a short sling = $\frac{2}{3}W$.	For short slings provided the angle between the legs is not more than 80 degrees.	54	3
13	$P = \frac{W}{g}(1 + fn)$	Calculating gain in tackles.	55	6

TABLE 51.—SIZES OF ROADBEARERS FOR BRIDGES, AND RAFTERS FOR DUG-OUTS

(A maximum moving load of 2 tons on one axle is allowed for.)

The table shows the number of roadbearers of different scantlings required for various spans.

Width of roadway has been taken as 9 ft. and the decking must be 3 in. thick.

	Span in feet					
	5	7	9	11	13	15
Scantling on edge (in inches)—						
6 × 2	9	13	—	—	—	—
9 × 2	5	7	8	10	11	13
7 × 2½	6	8	10	12	—	—
6 × 3	7	9	11	—	—	—
8 × 3	5	6	7	8	10	11
9 × 3	5	5	6	7	8	9
4 × 4	10	—	—	—	—	—
5 × 4	7	10	12	—	—	—
7 × 4	5	6	7	8	10	11
9 × 4	5	5	5	6	6	7
5 × 5	6	8	10	12	—	—
7 × 5	5	5	6	7	8	9
9 × 5	5	5	5	5	5	6
6 × 6	5	5	6	8	9	10
8 × 6	5	5	5	5	6	6
8 × 8	5	5	5	5	5	5
9 × 9	5	5	5	5	5	5
Round spars, average diameter—						
5 inches	9	12	—	—	—	—
6 „	6	8	10	12	—	—
7 „	5	5	7	8	9	11*
8 „	5	5	5	6	7	8
R.S.J. (in inches)—						
5 × 3 or larger	5	5	5	5	5	5
4 × 3	5	5	5	5	6	7
4 × 1¾	5	6	8	10	11	—
3 × 3	5	5	6	7	9	10
3 × 1½	7	10	—	—	—	—
20 lb. Decauville rail ...	6	8	10	12	—	—
80 lb. rail	5	5	5	5	5	5

* Where there is more than one 15-ft. span, eleven 7-in. spans cannot be placed on the transom.

The above table is calculated for a working stress in timber of ½ ton per sq. in. and in steel of 7½ tons per sq. in.

TABLE 52.—SAFE UNIFORMLY DISTRIBUTED DEAD LOADS IN LB. THAT CAN BE SUPPORTED BY GIRDERS OR RAILS OVER DIFFERENT SPANS.

(If the load is concentrated in the middle of the girder or rail only half these loads are safe.)

Span in feet	8 in. × 4 in. R.S.J. weight 18 lb. a ft.	6 in. × 3 in. R.S.J. weight 12 lb. a ft.	5 in. × 3 in. R.S.J. weight 11 lb. a ft.	40 lb. steel rail weight 13⅓ lb. a ft.	60 lb. steel rail weight 20 lb. a ft.	80 lb. steel rail weight 26⅔ lb. a ft.
4	37,500	18,700	14,500	9,720	17,770	26,800
5	30,000	15,000	11,700	7,775	14,200	21,450
6	25,000	12,500	9,700	6,480	11,500	17,875
7	21,400	10,600	8,300	5,550	10,150	15,320
8	19,900	9,300	7,200	4,860	8,880	13,400
9	16,600	8,200	6,400	4,320	7,890	11,900
10	15,000	7,400	5,800	3,890	7,100	10,725
11	13,500	6,700	5,200	3,530	6,460	9,750
12	12,500	6,200	4,800	3,240	5,900	8,940

TABLE 53.—LOADS ON RAFTS AND BRIDGES DUE TO LIGHT LOADS

(For other classification, *see* Tables in M.E., Vol. III)

Item No. (1)	Vehicle (2)	Weight, fully loaded		Distance axle to axle (5)	Distance towing eye to front axle when fitted for towing (6)	Overall width (7)	Overall height (8)	Overall length			Wheel track centre to centre (12)	Width of tyres (13)	Horse-drawn or mechanized (14)	Remarks (15)
		Front or limber axle (3)	Rear or gun axle (4)					with pole limbered up (9)	without pole limbered up (10)	when fitted for towing (11)				
		tons	tons	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.	H or M	
1	Wagon, limbered G.S. front, Mk. I, rear, Mk. II	1·44	1·44	8 0	—	6 4	4 8	22 0	12 11	—	5 0	2¼		(*a*) Without shield; 6 ft. 6 in. with shield.
2	3·7-in. howitzer, Mks. I–IIIR, carriages ...	—	0·71	—	—	6 6	4 7(*a*)	10 10	—	—	3 11	2	H	
3	Q.F., 13-pr., carriage and limber	0·69	0·98	9 11	—	6 3	4 9	25 9	17 2	—	5 0	3	H	
4	Q.F., 13-pr., ammunition wagon and limber ...	0·79	0·85	7 3	—	6 3	5 0	21 4	12 9	—	5 0	3	H	
5	Q.F., 18-pr., Mks. IIITR–VR carriage and Mk. IIR wagon limber	—	—	12 9	6 0	6 9	5 4	—	—	24 4	5 3	3	M	
6	Q.F., 18-pr., Mks. V–VR carriage and Mk. II or Mk. III limber	0·84	1·48	12 11	—	6 9	5 2½	30 7	21 7	—	5 3	3	H	
7	Q.F., 18-pr., Mk. II ammunition wagon and Mk. II limber ...	0·95	1·0	7 5	—	6 3	5 2	21 6	12 11	—	5 0	3	H	
8	4·5-in. howitzer, Mks. I–IR carriage and limber	0·84	1·39	10 0	—	6 3	5 0	25 7	16 8	—	5 0	3	H	(*b*) Vehicles of the light load class marked thus cannot use the tracked raft, F.B.E. (*c*) Normally tows a medium load. (*d*) Only the lightest and heaviest of the cars of these types in use in the Service are shown.
9	4·5in. howitzer, ammunition wagon and limber ...	0·81	1·22	8 7	—	6 3	5 0	23 0	14 3	—	5 0	3	H	
10	4·5-in. howitzer, Mk. IR carriage and ammunition wagon ...	—	—	10 11	7 3	6 3	5 0	—	—	21 11	5 0	3	M	
11														
12														
13														
14														
	4-wheeled M.T. Vehicles (light)— Cars—								Overall Length					
15	2-seater Austin, 7-H.P. ...	0·24	0·48	6 3	—	4 1	4 11	—	9 1	—	3 3½	4	M	
16(*d*)	4-seater, Jowett	0·03	0·60	8 6	—	4 6	5 11	—	12 8	—	3 9	4·4	M	
17(*d*)	4-seater, Vauxhall O.D.	0·67	1·36	10 9½	—	5 9	6 9	—	14 10	—	4 8¼	5·3 (135m/m)	M	
18(*d*)	Closed, Austin, 12-H.P. ...	0·48	0·96	9 4	—	5 7	6 1	—	13 6	—	4 8	5	M	
19(*d*)	Closed, Austin, 20-H.P. ...	0·80	1·60	11 4	—	5 9½	6 4	—	15 7	—	4 9½	6	M	
20(*d*)	Armoured, Rolls Royce ...	1·95	2·75	12 0	—	6 4	8 4	—	16 2	—	4 11	13 twin	M	
	Vans—													
21	Ford T. (7-cwt.)	0·41	0·82	8 4	—	5 8	6 10	—	11 8	—	4 8½	3½	M	
22	Morris R.S. (12-cwt.)	9·85	1·72	9 0	—	5 11	7 9	—	13 8	—	4 8	7½	M	

TABLE 53—*continued*

Item No. (1)	Vehicle (2)	Weight, fully loaded: Front or limber axle (3)	Weight, fully loaded: Rear or gun axle (4)	Distance axle to axle (5)	Distance towing eye to front axle when fitted for towing (6)	Overall width (7)	Overall height (8)	Overall length: with pole limbered up (9)	Overall length: without pole limbered up (10)	Overall length: when fitted for towing (11)	Wheel track centre to centre (12)	Width of tyres (13)	Horse-drawn or mechanized (14)	Remarks (15)
		tons	tons	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.	H or M	
23(*b*)	Lorries, 30-cwt., Thornycroft A. 1, Guy B.A., Halley W., Karrier W.D., Vulcan V.W.D., Crossley B.G.T. 2, Albion R.24	1·28	2·56	11 6	—	6 5	9 7	—	17 11	—	5 0¼	7	M	
24(*b*) (*c*)	Tractor, Thornycroft "Hathi"	2·73	2·13	11 6	—	6 10½	6 5	—	17 0	—	6 1	7 or 8	M	
25														
26														
27														
28														
29														
30														

Item No. (1)	Vehicle (2)	Weight, fully loaded: Front or limber axle (3)	Weight, fully loaded: Rear or gun axle (4)	Distance axle to axle: Front to middle (5)	Distance axle to axle: Middle to rear (5)	Distance towing eye to front axle when fitted for towing (6)	Overall width (7)	Overall height (8)	Overall length: with pole limbered up (9)	Overall length: without pole limbered up (10)	Overall length: when fitted for towing (11)	Wheel track centre to centre (12)	Width of tyres (13)	Horse-drawn or mechanized (14)	Remarks (15)
	6-wheeled M.T. Vehicles (Light)— Cars—	tons	tons	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		H or M	
31(*b*)	Open, Morris T.D.	1·08	1·07	8 8½	3 0	—	6 4½	6 8	—	16 4	—	4 8	11-in. Twin.	M	
32(*b*)	Closed, Morris 6D., Crossley	1·05	1·05	8 11	3 2	—	6 8	7 3	—	16 9	—	4 8	7-in. Single	M	
33(*b*)	Armoured, Crossley	1·5	1·6	7 9	3 3	—	6 2	7 11	—	14 10	—	5 4	7·5-in. Single	M	
34(*b*)	Ambulances, Morris D., Vulcan V.S.W.	1·30	1·53	8 11	3 4	—	6 6	9 1	—	16 4	—	5 0½	7·5-in. Single	M	
	Lorries—														
35(*b*)	30-cwt., Morris D	0·87	1·68	8 8½	3 0	—	6 0	8 3	—	16 8	—	4 8	11-in. Twin.	M	
36(*b*)	30-cwt., Crossley	1·06	1·75	8 5	3 3½	—	6 3	8 6	—	17 0	—	4 9 5 2¾	7·5-in. Single. 11-in. Twin.	M	
37(*b*)	30-cwt., Vulcan V.S.W., Garner	1·4	1·7	7 11½	3 4	—	6 8	8 6	—	16 5	—	4 5⅝ 5 0¼	7·5-in. Single. 11-in. Twin.	M	
38(*b*)	30-cwt. ...	0·79	1·67	8 8	3 0	—	6 6	9 9½	—	18 3	—	4 8	7·5-in. Single.	M	
39															
40															
41															
42															
43															
44															

TABLE 53.—*continued*

Item No. (1)	Vehicle (2)	Weight fully loaded. Single axle (3)	Distance from rear axle of towing vehicle to front axle of trailer (4)	Over-all width (5)	Over-all height (6)	Over-all length (7)	Wheel track, centre to centre (8)	Overall width of tyres on one wheel P.=Pneumatic. S.=Solid. (9)	Remarks (10)
		tons	ft. in. ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
	Light service trailers—								
45	2-wheeled, 10-cwt., G.S. body...	0·95	8 4 to 8 9	5 11	4 7	8 3	5 1	5½-in. Single, P.	The classification in this table is for trailers without the towing vehicles. Trailers must be manhandled on the tracked raft, F.B.E. Any vehicle towing trailers Nos. 1 to 8 may cross folding boat equipment bridge provided the vehicle itself may cross.
46	,, ,, water tank			5 11	4 6	8 3	5 1		
47	,, ,, petrol tank			5 11	4 4	8 3	5 1		
48	,, 15-cwt., G.S. body...	1·60	10 3 to 10 6	6 9	5 6	11 0	5 7	7½-in. Single, P.	
49	,, ,, water tank	1·90		6 9	5 6	11 3	5 7		
50	,, ,, petrol tank	1·45		6 9	5 6	11 0	5 7		
51	,, ,, kitchen ...	1·30	9 4 to 9 9	6 8	6 6	9 5	5 5	7½-in. Single, P.	
52	,, ,, 4-man ammunition	—	9 4 to 9 9	5 4	3 9	11 2	4 6¼	5¼-in. Single, P.	
53									
54									
55									
56									
57									
58									

Item No.	Vehicle	Weight without crew or equipment	Weight fully loaded	Tracks		Width from outside to outside of tracks	Overall width	Overall height	Overall length	Distance from centre contact point of track to towing eye	Remarks
				Length resting on ground	Width						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		tons	tons	ft. in.	in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	
	Light tracked vehicles—										
59	Carden Lloyd, Mk. VI...	1·35	1·90	3 0	5¼	5 7	5 7	3 4	8 1	—	(*a*) Light loads which cannot use the tracked raft.
60	Carden Lloyd, Mks. VIA and VIB	1·78	2·14	3 0	5¼	5 8½	5 8½	4 11	8 4	—	
61	Tractor, light, G.S. ...	1·30	1·80	3 4	10⅞	3 8⅞	5 0	4 2	6 7	—	(*b*) May use the tracked raft if unloaded to reduce weight to 3 tons.
62 (*a*)	Tanks, light, Mks. II, IIA, IIB and III ...	3·78	4·35	6 4	9½	6 0	6 3½	6 10	11 10½	—	
63 (*a*)	Tanks, light, Mk. IV ...	3·40	4·05	6 6	9½	6 5¾	6 8¼	6 9½	10 9½	—	
64 (*b*)	Dragons, light, Mk. I...	2·65	3·20	6 4	10½	6 1	6 2	4 1	11 6	5 9	
65 (*a*)	Dragons, light, Mk. II...	3·30	4·00	6 4	9½	6 1	6 6	6 0	12 3	5 9	
66											
67											
68											
69											
70											
71											
72											

CLASSES

Note.—The fi roadbearers on fixed supports ; they cover the impact effect o ised for girders or roadbearers on floating supports or for decking.

Class of load	Types	Notes
(1)		(15)
		ntry in single file in marching order, crowded at a check. 0·0625 tons

TABLE 54.—BRIDGE CLASSIFICATION—DETAILED LIMITS OF LOAD CLASSES

Note.—The figures given in columns 3 to 14 are for use in determining the transverse strength of girders or roadbearers on fixed supports; they cover the impact effect of live loads for single-line traffic. They do not allow for the weight of the bridge and cannot be used for girders or roadbearers on floating supports or for decking.

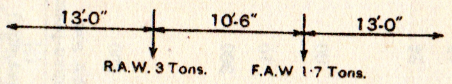
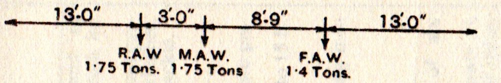
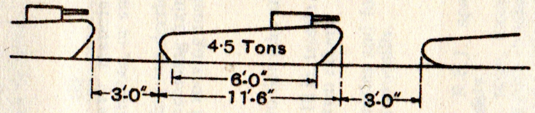
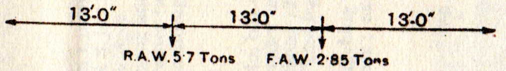
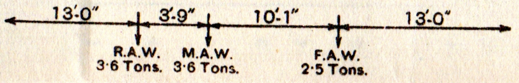
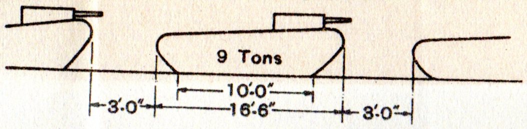
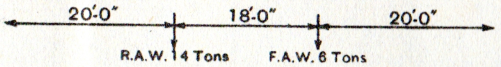
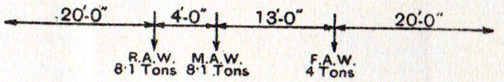
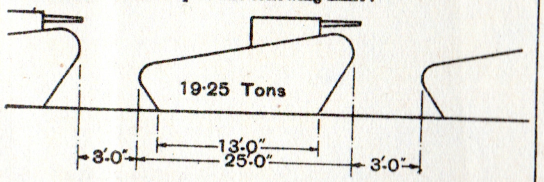
Class of load	Types of loading and the minimum permissible spacing	Total E.U.D.D.L. in tons at spans from 10 to 150 ft.											E.U.D.D.L. in tons per ft. at spans above 150 ft.	Notes
		10′	15′	20′	30′	40′	50′	60′	75′	100′	125′	150′		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
ASSAULT	Infantry in single file at 5 ft. interval	← 0·025 tons per ft. run →												For infantry in single file in marching order, crowded at a check, 0·0625 tons per ft. run should be allowed.
PACK	(*a*) Infantry in file (*b*) Cavalry in single file (*c*) Pack transport (*d*) Cycles and motor cycles, without sidecars } Crowded at a check ...	← 0·125 tons per ft. run →												
LIGHT	(*a*) Infantry in fours (*b*) Cavalry in half sections (*c*) Motor cycles with sidecars (*d*) Horse-drawn vehicles } Crowded at a check (*e*) 4-wheeled vehicles up to the following limits :—  13′·0″ 10′·6″ 13′·0″ R.A.W. 3 Tons. F.A.W 1·7 Tons. (*f*) 6-wheeled vehicles up to the following limits :—  13′·0″ 3′·0″ 8′·9″ 13′·0″ R.A.W 1·75 Tons. M.A.W. 1·75 Tons F.A.W. 1·4 Tons. (*g*) Tracked vehicles up to the following limits :— 	9·0	9·0	9·3	11·2	13·3	16·0	18·6	23·8	31·4	39·0	46·6	0·311	(i) These figures allow for vehicles moving in a continuous column at the minimum practicable spacing; they also allow for vehicles halted and fully closed up. (ii) The axle spacings and the length of the track bearing shown in column (2) are the minimum permissible for the loads given. (iii) All light, horse, and field artillery, whether horse or tractor drawn, is included. (iv) Service 2- or 4-wheeled trailers, except 4-wheeled pontoon trailer, towed by M.T. vehicles in this class, are also included. (v) Civilian vehicles, specified as motor-cars under the Road Traffic Act, 1930, and Statutory Rules and Orders, 1931, No. 4, are limited to 2·5 tons unladen weight. They may be allowed up to the limits of laden weight shown in column (2).
MEDIUM	(*a*) 4-wheeled vehicles up to the following limit :—  13′·0″ 13′·0″ 13′·0″ R.A.W. 5·7 Tons F.A.W. 2·85 Tons (*b*) 6-wheeled vehicles up to the following limit :—  13′·0″ 3′·9″ 10′·1″ 13′·0″ R.A.W. 3·6 Tons. M.A.W. 3·6 Tons. F.A.W. 2·5 Tons. (*c*) Tracked vehicles up to the following limit :— 	17·1	17·1	17·8	21·4	22·0	24·1	29·1	34·7	47·0	57·9	69·3	0·462	(i) These figures allow for vehicles moving in a continuous column at the minimum practicable spacing; they also allow for vehicles halted and fully closed up. (ii) The axle spacings and the length of the track bearing shown in column (2) are the minimum permissible for the loads given. (iii) Medium artillery is included but not dragons, Mks. II*, III, IIIA, and IIIB, used for towing this artillery. (iv) The Q.F., 3-in., 20-cwt. gun on platform, travelling A.A. mounting, 2-wheeled, Mk. I and 4-wheeled, Mks. I and II, are included, but not tractors F.W.D. or scammell used to tow the 4-wheeled platforms. The 2-wheeled platform may be excluded by the vehicle used to tow it. (v) Service 2- or 4-wheeled trailers, except 4-wheeled pontoon trailer, towed by M.T. vehicles in this class, are included. (vi) Single-deck coaches are included in this class. Other civilian vehicles specified as heavy motor-cars under the Road Traffic Act, 1930, and Statutory Rules and Orders, 1931, No. 4 may be allowed up to the limits shown in column (2). Civilian vehicles specified as tractors under the same Act are limited to 7·25 tons total weight and fall within this class.
HEAVY	(*a*) 4-wheeled vehicles up to the following limit :—  20′·0″ 18′·0″ 20′·0″ R.A.W. 14 Tons F.A.W. 6 Tons (*b*) 6-wheeled vehicles up to the following limit :—  20′·0″ 4′·0″ 13′·0″ 20′·0″ R.A.W. 8·1 Tons M.A.W. 8·1 Tons F.A.W. 4 Tons (*c*) Tracked vehicles up to the following limit :— 	36·0	36·6	39·5	44·0	44·0	44·0	45·4	53·5	68·7	87·0	105	0·697	(i) These figures allow for vehicles moving in a ocntinuous column at the minimum practicable spacing; they also allow for vehicles halted and fully closed up. (ii) The axle spacings and the length of the track bearing shown in column (2) are the minimum permissible for the loads given. (iii) The 4-wheeled vehicle shown in column (2) is theoretical. It is unlikely that vehicles of this type will be used. (iv) Heavy artillery is included. (v) Double-deck 'buses are included in this class. All other civilian vehicles specified by the Road Traffic Act, 1930, and by Statutory Rules and Orders, 1931, No. 4, fall within this class, namely :— *Max. laden weight* Heavy motor-cars, 4-wheeled ... ... 12 tons. ,, ,, 6-wheeled ... ... 19 tons. Steamers, 4-wheeled ... ... 14 tons. Light locomotives ... ... 11·5 tons. Heavy locomotives ... ... 19 tons. Special vehicles above these limits and vehicles towing trailers must be considered individually. (vi) The 4-wheeled vehicle is purely theoretical and is in effect equivalent to the 6-wheeled vehicle on long spans; the figures given in columns (3), (4), and (5), therefore, take into consideration a maximum axle load of 12 tons only.
	6-wheeled vehicles at (*b*) above at 15 yds. spacing, tanks at (*c*) above at 7 yds. spacing and all medium loads unrestricted	31·2	36·6	39·5	44·0	44·0	44·0	44·0	44·8	47·0	57·9	69·3	0·462	(i) These figures are for heavy bridges on which traffic restriction can be enforced. (ii) The 4-wheeled vehicle, being theoretical, has not been considered in these figures.

TABLE 55.—MAN-HOURS REQUIRED FOR VARIOUS TASKS IN CONNECTION WITH BRIDGING OPERATIONS

Item (1)	Nature of work (2)	Total man-hours required (approximate working by daylight) (3)	Normal working party (4)	Remarks (5)
1	Man-handling heavy material, such as R.S.Js., baulk timber, or steelwork for bridges.	5½ man-hours per ton.	10	Size of party depends on weights to be moved.
2	Rigging and erecting one derrick and preventer tackle, including fixing winches, anchorages, and reeving main tackle.	200	40	Assuming no difficulty in getting stores across the gap. System of derricks of a similar nature to that used for large box girder bridge. Bigger or more complicated systems. will take longer.
3	Ditto, but with two derricks and two preventer tackles.	360	60	Similar to 120-ft. Hopkins bridge launching gear.
4	Building 12 in. × 12 in. trestle up to 15 ft. Three legs and two rakers.	40	10	Assuming timber dumped at site, but not cut to length, and five cross-cut saws available.
5	Launching two trestles and forming into pier; excluding mudsills.	80	20	Assuming trestles built at site and no complications in launching, *i.e.* trestles upended at or near final position or slid downways. More men will be required if trestles have to be carried.
6	Launching 20-ft. R.S.J. span, of six 12 in. × 5 in. joists.	24	16	Including short carry and rolling out on timber ways. Not including fixing.
7	Completing R.S.J. span, fixing joists at ends and centres with chocks and bolts, fixing spiking rail, and carrying and fixing decking and curbs.	48	12	Assuming material prepared beforehand and decking ready at hand. Not including hand rails. Time up to one hour can be saved on this if decking has holes bored for spikes beforehand and curbs are prepared for bolts.
8	Making plank road, 18-ft. double roadway. Levelling ground and laying planks. Good ground.	14 per yd.	—	Working party depends on length to be made. One 3-ton lorry per 8 yds. required for material.
9	Ditto. Bad ground with shell-holes, etc.	16 per yd.	—	One 3-ton lorry per 7 yds. required for materials. Includes sleepers under

APPENDIX V

DEMOLITIONS

TABLE 56.—APPROXIMATE QUANTITIES OF EXPLOSIVES CARRIED IN THE FIELD

Detail (1)	Division				Cavalry Division				Corps Troops		
	Each Fld. Coy., R.E. (2)	Div. Amn. Coy. (3)	Maint. Coy. (4)	Total in front of rail-head (5)	Fld. Sqn. R.E. (6)	Cav. Div. Amn. Coy. (7)	Cav. Maint. Coy. (8)	Total in front of rail-head (9)	Each Army Troops Coy. R.E. (10)	Corps Troops Amn. Coy. (11)	Corps Troops Maint. Coy. (12)
1. Gun-cotton, dry primers, field, 1-oz.	720	540	240	2,940	480	480	240	1,200	720	540	240
2. Gun-cotton, wet, slabs, field	728	546	280	3,010	1,120	1,120	560	2,800	728	546	280
3. Detonators, No. 8	400	300	150	1,650	400	400	200	1,000	400	300	150
4. Detonators, electric, No. 9	200	150	75	825	400	400	200	1,000	200	150	75
5. Fuze, safety, No. 11 (ft.) ...	1,344	1,008	528	5,568	1,152	1,152	576	2,880	1,344	1,008	528
6. Fuze, instantaneous, detonating (ft.) ...	1,600	1,200	800	6,800	1,600	1,600	800	4,000	1,600	1,200	800
7. Matches, fuzee, safety ...	400	300	150	,650	600	600	300	1,500	400	300	150

In addition, a strategic reserve of explosives will be maintained to ensure an adequate supply being available for demolitions on a strategic scale.

TABLE 57.—SUMMARY OF PROGRESS DATA

1. *Cutting holes in abutments or retaining walls.*—

(*a*) In good brickwork :—

Hole 1 ft. square or less—	*With hand tools*	*With portable pneumatic tools*
1 ft. deep	about 40 minutes	About one-third of these times.
2 ft. deep	about 90 minutes	
3 ft. deep	about 150 minutes	
4 ft. deep	about 240 minutes	

Larger holes in proportion to the side (not to the area).

(*b*) In good stone masonry or hard concrete :—

Hole 1 ft. square—	*With hand tools*	*With portable pneumatic tools*
1 ft. deep	4 or 5 times these figures ...	Up to 40 minutes.
2 ft. deep		Up to 90 minutes.
3 ft. deep		Up to 150 minutes.
4 ft. deep		Up to 240 minutes.

Other holes in proportion to their area.

2. *Cutting holes in road or floor surfaces.*—

Per 1,000 cubic inches evacuated	*With hand tools*	*With portable pneumatic tools*
In hard concrete	About 80 mins.	About 16 mins.
In metalled road surface ...	About 20 mins.	About 4 mins.

3. *Auger-holes in soft media.*—

Probable progress by two men with frequent reliefs, under entirely favourable conditions, with a 6-in. earth auger, would be an average of 1 ft. in 7 or 8 minutes up to a length of 10 ft. With longer holes, hard or stony ground, etc., progress will rapidly diminish.

4. *Boreholes in hard media.*—

Length of vertical hole, drilled by three men with hand tools per hour, in inches multiplied by square of diameter of hole in inches, should be about—

16–24 ...	in granite.
21 ...	in whinstone.
24 ...	in slate.
28 ...	in limestone (hard).
32 ...	in sandstone.
30–50 ...	in concrete.
80 ...	in brickwork (with a minimum size of hole of 2 in. in brickwork).

Progress in horizontal holes will be about half the above, and still less in holes sloping upwards.

With machine drilling, progress on the average should be five to ten times as fast as hand work, and is not appreciably affected by direction.

With portable pneumatic tools, progress for individual short holes will be from 20 to 40 times as fast as for hand work, provided the hole is conveniently placed.

APPENDIX VI

WATER SUPPLY

Man-hours data

1. *L. and F. Pump.*—

i. 2 men produce 12 g.p.m. short periods, small lift.
ii. 2 men produce 10 g.p.m. short periods, large lift.
iii. 2 reliefs of 2 men required if lift is over 35 ft. 3 reliefs of 2 men are best for long periods.

2. *Trough, waterproof.*—

6 men erect 1 in 20 minutes.

3. *Tank, waterproof.*—

i. Home pattern.—6 men erect 1 in 30 minutes.
ii. Indian pattern.—8 men erect 1 in 15 minutes.

4. *Corrugated iron trough with timber frames.*—

2 men erect 16 ft. trough in 2 hours.

5. *Ablution bench.*—

2 men erect 19-ft. bench in 2 hours.

6. *Framed tarpaulin reservoir.*—

Erecting	8 men, 4 hours.
Making outlet	2 men, 15 minutes.
Joining sheets	4 men, 30 minutes.

7. 4,000-*gal. raised canvas tank.*—

i. Using tubular scaffolding.

(*a*) Erect scaffolding	50 man-hours
(*b*) Placing floor	26 ,,
(*c*) Fixing canvas	20 ,,
(1 N.C.O. and 12 men)	96 man-hours

ii. Using timber tower ... ... 560 man-hours.

8. *Norton tube well.*—

i. Driving in flinty soil : 5 men 12 ft. in 1 hour.
ii. Driving in soft soil : 5 men 20 ft. in 1 hour.

9. *Water point.*—

i. Supply from adjacent 3-in. main.
3 water vehicles filling standards (Plates **197, 198**).
6 troughs, horse (Plate **191**).
1 water bottle point (Plate **196**).
1 N.C.O. and 22 men : 2 days.

ii. Supply from adjacent main.
2 400-gal. iron tanks on staging.
1 water-vehicle filling standard.
75-ft. corrugated iron troughing.
1 N.C.O. and 10 men : 7 days.

iii. Supply from adjacent main.
Main tapped and 62 ft. 1-in. piping laid.
1 400-gal. iron tank on staging.
1 water vehicle filling standard.
28-ft. run corrugated iron troughing.
20 men : 9 hours.

10. *Screwed piping.*—

i. *Cutting 4-in. with wheel cutter.*
2 men : 1 pipe 30–40 minutes.

ii. *Screwing.*
(*a*) 4-in.—2 men 30–40 minutes.
(*b*) 1½-in.—1 man 20–30 minutes.

iii. *Tapping main.*
2 men : 20 minutes.

iv. *Trenching.*
(*a*) Trench 3-ft. 6 in. × 2 ft. deep for 4-in. pipe 15-ft. run/man/day.
(*b*) Trench 3 ft. 6 in. × 1 ft. 6 in. deep for 2-in. pipe 18-ft. run/man/day.
Ditto in easy sand.
18-ft. run/man/3 hours.
(*c*) Trench 1 ft. 6 in. × 1 ft. deep :—
100 men in 1 day—½ mile in hard ground.
100 men in 1 day—1 mile in medium ground.
100 men in 1 day—1¼ miles in easy ground.

v. *Carrying.*
(*a*) 1 man in 1 hour carries 42 lb. pipe 1 mile.
(*b*) 1 man carries one 6-in. pipe 14-ft. long ^{2} mile per 8 hours shift in good weather.

vi. *Laying.*
(*a*) 10 men : 25 yards in 1 hour.
(*b*) 2-in. pipe : 9 man-hours per 100 ft. run.
3-in. pipe : 12 man-hours per 100 ft. run.
(*c*) 2-in. pipe : 8 men in 1 hour : 225 ft. run.
3-in. pipe : 10 men in 1 hour : 150 ft. run.
4-in. pipe : 12 men in 1 hour : 125 ft. run.
6-in. pipe : 17 men in 1 hour : 100 ft. run.

vii. *Screwing up joints.*

	Fitters	Labourers	Ft. run per man-hour
2-in.	2	6	25
3-in.	2	8	15
4-in.	2	10	10

viii. *Making good.*
2-in. 1 joint 1 man in 5 minutes.
4-in. 1 joint 2 men in 10 minutes.
6-in. 1 joint 2 men in 15 minutes.

ix. *Laying, screwing up, and making good.*—
30 to 40-ft. run per man per day.

11. *Victaulic piping.*—

i. *Making joint.*
2 men 2 minutes.

ii. *Cut and groove 2 or 4-in. pipe.*
1 hour per pipe.

iii. *Cutting 4-in. pipe with parting tool.*
2 men 15–20 minutes.

iv. *Joining up.*

	Fitters	Labourers	Ft./hour	Ft./man-hour
3-in. pipe ...	2	4	600	100

4-in. pipe (difficult ground) 5 ft./man/hour.

v. *Laying, jointing and making good 4-in. piping on surface.*
Laying : 2 lorries each with 6 men.
Jointing and making good : 1 officer, 6 N.C.Os., 30 men.
Rate of progress : 1 mile a day. ¾ mile a day in difficult country.

APPENDIX VII

PRACTICAL NOTES ON THE USE OF PNEUMATIC TOOLS

1. The power to drive pneumatic tools is supplied from a compressor driven by a petrol engine. The compressed air is stored in a container and supplied to the tools by flexible hose which is available in 50-ft. lengths.

2. Before connecting the hose to the compressor or tools make sure that the clip securing the hose to the hose connector is firmly fixed. A leather washer should be inserted between the hose and compressor connection and also between the hose and tool connection. This prevents loss of air and unnecessary noise.

3. Before connecting any tool to the hose, turn on the air and blow through the hose. This will remove any dirt, etc., which may be in the hose and prevent the same from being carried over into the tool. This is *very important* as any foreign matter entering the tools will cause unnecessary wear and may put the tool out of action, causing loss of time and expense in repairs.

4. Before actually turning on the air to the tool in use, make an examination of all nuts, springs, etc., and tighten if necessary.

5. Keep the hose free from kinks when in use, as these are often the cause of blown joints and burst hose.

6. When using the tools always keep them pointing towards the ground and away from the feet, as vibration may loosen the tool and cause it to fly out. Similar precautions should be taken when working on a vertical face.

7. When coiling hose do so in a clockwise direction similar to the method adopted for cordage.

8. The tools should be lubricated from time to time with a thin oil according to the particular maker's instructions. The service oil usually used internally is M.60.

9. The pneumatic tools and accessories for use in the field with the portable compressor set comprise rock drills and steels, picks, spades, woodborers and air hose. Details of these tools are as follows :—

Rock drills.—These are known in the trade as hand hammer drills or jackhammers. The service type are intended for drilling up to a depth of 5 ft., holes finishing not less than 1½-in. diameter in rock, concrete, etc. They weigh 26 lb. and can be operated by one man for drilling in either the vertical or horizontal direction. Air consumption is approximately 50 cu. ft./min. at 80 to 100 lb./sq. in. The action of the piston on the drill steel is simply that of a hammer blow ; there is no rotation of the piston. Splines on the piston, however, acting on a ratchet, impart a rotary motion to the drill steel on each return stroke of the piston.

During drilling the hole is constantly flushed by means of live air which passes through the drill case to the hollow drill steel, and so clears the hole of chippings, etc. It should be noted that by means of a through flushing device the full pressure of air can be directed to the point of the hollow drill steel even while the tool piston is stationary.

Drill steels.—These are issued in three lengths, 20-in., 40-in., 60-in., with bit diameters 1¾-in., 1⅝-in., and 1½-in. respectively. The object of this is to compensate for wear in the bit during drilling and to avoid jamming in the hole when changing steels.

Pneumatic picks.—These tools are used for breaking up concrete, brickwork, etc., loosening road surfaces and general excavation and demolition work.

They are purely percussive tools, no rotary motion being imparted to the steels. Otherwise they are similar in operation to the drill. Two sizes of picks are available weighing 18 and 22 lb. and consuming approximately 30 and 32 cu. ft./min. of air respectively, at 80 to 100 lb./sq. in. Pick steels are normally 18 in. long. Their sharpening should present no difficulty to a blacksmith as the points are either plain or chisel ended.

The tool should be used with a circular movement keeping the point in the one position, *i.e.* do not let the pick jam in the hole, which will certainly occur if the handle of the tool is not moved in a circle or from side to side. This is particularly desirable when working on concrete and applies to horizontal as well as vertical faces. Do not allow the point of the tool to become too blunt as penetration will become difficult. Either change steels or sharpen on a grindstone taking care to keep cool and not to draw the temper.

Pneumatic spade.—These tools are useful for digging in chalk, clay, gravel or soil and should be used in conjunction with a mate shovelling. Again they are purely percussive tools similar in operation to the pick. The spade weighs 28 lb. complete and consumes approx. 30 cu. ft./min. of air at 80 to 100 lb./sq. in.

Woodborers.—Whereas the foregoing are all reciprocating tools, the woodborer is a rotary tool and consists of a high-speed air motor having four cylinders designed very much on motor car engine practice and similarly enclosed and balanced. The pistons are arranged in two pairs in a V position. The speed of the motor being much higher than that required in the drill, the power is transmitted through reduction gearing. Ball bearings are fitted throughout and the drill is reversible.

This size of woodborer is capable of drilling a 1-in. hole in hard or wet wood to a depth of 24 in. It is complete with a set of ¼-in. to 1-in. auger-bits, and is a valuable tool for boring timber for bolts, etc., and for demolition of trees.

It is important to keep the auger and tool in a correct vertical or horizontal position as the case may be. When using long augers it is difficult for the operator to ascertain if his position is correct and he should detail another man to stand away from the tool and check him from time to time. The auger will penetrate very quickly but should be held in check in order that the chips may clear. A clogged auger usually means a broken or bent auger and therefore should be cleared if inclined to stick.

10. A set of hand tools for dressing bits consists of:—

1 Dolly
1 Sow
1 Flatter
1 Spreader.
1 Swage.
1 Punch.

In addition, an anvil and portable forge are provided. The forge can be blown from the compressor.

If bits are allowed to become very blunt, *i.e.* if the cutting edges are worn almost flat, it will be necessary to reforge the bit. This can be done in the field with the blacksmith's tools, but takes about twice as long as mere dressing.

It should also be noted that a very blunt steel will produce a hole that is undersize in diameter.

Dressing.—Drill steel has a carbon content of between 0·7 and 0·8 per cent.

(*a*) It should be worked on the anvil at an orange heat (about 950° C.) with the hand tools. If only a small amount of work on it is required, full forging heat is unnecessary. Heat slowly, thoroughly and uniformly.

(*b*) Do not reheat more than is necessary but avoid working at a black red heat.

After dressing, hardening and tempering are necessary. These processes involve no special methods and need only the ordinary treatment necessary for any high-class steel.

Hardening and tempering.—Heat slowly to a dull cherry red (740° C.) about 2½ in. of the end of the bit. Quench about 1½ in. in water till cold, moving the bit up and down to avoid cracks developing around the water line. Then polish one cutting edge and with the heat remaining in the rest of the metal, draw the temper to a golden yellow colour (240° C.) and quench off.

Shanks.—The shank of a drill steel must be square with its axis, otherwise the drill hammer may be damaged. Shanks require to be examined frequently and trued up.

APPENDIX VIII

STANDARD TESTS OF ELEMENTARY FIELD ENGINEERING

(*See also* Engineer Training)

To be fit to take his part in collective fieldwork's training every sapper should be able to carry out without hesitation the simple tests set out below.

During his recruit training every sapper must attain this standard. In order to keep up his efficiency it is desirable that he should be tested annually in at least a selection of these tests. It will not as a rule be possible in the time available to cover all the ground in one year, but if a number of tests from each category is selected each year the desired object will be attained.

Knotting, Lashing and Use of Spars

1. Coil a rope.
2. Make without hesitation any of the knots and hitches enumerated in Sec. **52,** and know their uses.
3. Whip the end of a rope.
4. Make a seizing.
5. Mouse a block.
6. Make the following lashings: square, diagonal, gyn, sheers, block to spar, picket holdfast, round.
7. Fish two spars.
8. Fit a maul or pickhelve as anti-twister to a tackle.
9. Reeve a block and tackle.
10. Make up a S.W.R. sling and fix on a sheers.
11. Attach a S.W.R. guy to a block or anchorage with and without bulldog clips.
12. Make an eye splice in cordage.
13. Make a short splice in cordage.
14. Withdraw a picket using (*a*) cordage, (*b*) chain.
15. Select by eye a spar of a given mean diameter.
16. Know the difference between a runner and lifting tackle and the theoretical advantage of different combinations.

Field Geometry

17. Measure a distance of 3 in, 6 in. and 9 in. with the hand and distances up to 7 ft. with hand, foot and pickhelve.
18. Measure a slope with the field level.
19. Lay off or measure any angle with the field level.
20. Level two pickets with the field level and straight-edge.
21. Drive the tops of two pickets to a given slope with the field level.
22. Plumb an upright.
23. Lay out a right angle without a field level by 3, 4, 5, method.
24. Lay out a right angle by eye with an error of not more than 2 degrees.
25. Pace a given distance with an error of not more than 5 per cent.

Earthworks and Obstacles

26. Know the dimensions and names of the parts of normal fire and communication trenches.
27. Excavate methodically and correctly in a standard trench in average soil in a 4-hour task 80 cu. ft. by day and 60 cu. ft. by night, pauses being given by the instructor.
28. Mark out a task describing the order of excavation to maintain a face. (M.F.E., Vol. I, 1933, Sec. 9, 2).
29. As one of a party of three carry out intensive digging (as in M.F.E., Vol. I, 1933, Sec. 8, 5, x).
30. Trace out any recognized trace of fire trench or C.T. by pacing, with reasonable accuracy.
31. Make templets for the three tasks of fire trench and C.T.
32. Make up the following standard trench accessories :—
    - i. " A " frame.
    - ii. Trench-board.
    - iii. X.P.M. gabion.
    - iv. X.P.M. revetting panel.
33. As one of a party of three make up a brushwood hurdle.
34. As one of a party of four make up a fascine.
35. Prepare and make fast wire anchorages for revetment in a standard trench.
36. Make up a knife-rest of wood or angle iron pickets.
37. Lay out stores correctly for D.A.F.
38. Put in screw or brushwood pickets for D.A.F.
39. Make without hesitation the fastenings for D.A.F. on screw and brushwood pickets.

40. Fill and lay sandbags for wall revetment.
41. Fill and lay sandbags for elbow-rest revetment.
42. As one of a party of five fill, carry and lay 60 sandbags in 45 minutes.
43. Cut and lay sods for revetment of an elbow rest.

USE OF TOOLS

44. Drill and march correctly with pick and shovel.
45. Demonstrate the correct use of pick and shovel and understand the reasons for the various points.
46. March on a task with tools and equipment.
47. Drive a 5-ft. picket with a maul to correct slope.
48. Use an adze.
49. Select correct size of auger and make a hole for a given size of bolt in a 12-in. by 12-in. baulk.
50. Drive in dogs correctly.
51. With another man saw a piece of 12-in. by 12-in. timber with a cross-cut saw cleanly and squarely in 10 minutes.
52. Saw through a 10-in. by 5-in. fir sleeper to a line with a hand saw in 4 minutes.
53. Drive three 4-in. wire nails in succession straight into a fir sleeper.
54. Use a billhook for clearing brushwood and a felling axe for felling small trees.
55. Sharpen cutting tools.
56. Use any of the pneumatic power tools.
57. As one of a pair, changing round, bore holes 2 ft. 6 in. deep with jumping and boring bars in brickwork, rock or concrete in . . . . minutes, according to nature of medium.
58. Point a 3-in. diameter picket with a hand axe in 1½ minutes.

DEMOLITIONS

59. Know the precautions to be taken when using gun powder, detonators, guncotton, etc.
60. Know the precautions to be taken before and during the firing of charges.
61. Know the precautions to be taken in the case of a misfire.
62. Prepare and light safety fuze with match and match box.
63. Calculate the time of burning of a given length of safety fuze and test.
64. Prepare F.I.D. for detonation.
65. Prepare primer, detonator and safety fuze for firing.
66. Prepare a charge for firing electrically.
67. Make a joint in electric cable correctly in 5 minutes.

68. Test a circuit for continuity.
69. Find a fault in electric leads by pricker test.
70. Test an exploder by fusion test.
71. Make up an ammonal sausage.
72. Make up an ammonal charge in a bag.
73. Make up an ammonal junction box.
74. Make all the F.I.D. connections in Plate **158.**
75. Fix a G.C. charge to a girder or rail.

WATER SUPPLY

76. Strip and refit a L. & F. pump and explain working and maximum lift.
77. Connect two lengths of victaulic piping.
78. Connect two lengths of screw-piping using chain pipe grips.
79. Fit up a horse trough and a canvas tank.
80. Strip and refit a Norton tube pump.
81. Prepare Norton tube well for cleaning tubes.
82. Prepare Norton tube well for tilting action.
83. Know how to work a syphon.

PONTOONING AND WATERMANSHIP

84. Row in good style pulling his weight in cutter or pontoon.
85. Know the parts of a boat.
86. Attach head and foot ropes to a trestle.
87. Adjust a trestle using the jacks.
88. Put on a diagonal tie and adjust it.
89. Make fast a racking chain.
90. Carry a chess correctly.
91. Make fast cable and buoyline to anchor and buoy.
92. Belay a cable.
93. Join two anchor cables.
94. Heave a 10-fathom breastline to a man standing 40 ft. away so that he can catch it. The standing end to be made fast.

BRIDGING

95. Make a fished joint in tubular scaffolding.
96. Put on a diagonal in tubular scaffolding.
97. Fix a sling to a suspension bridge transom.
98. Demonstrate the first two orders of leverage with a handspike or crowbar.
99. Prepare a pile for driving in different kinds of soil.
100. Know the parts of a framed trestle and how to put it together.

MINING

101. Make up standard mining setts.

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FIELD GEOMETRY.

Fig. 2.

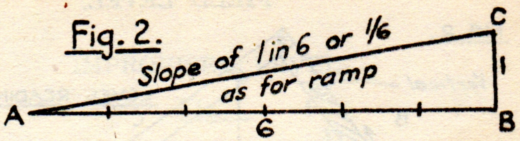

C
Slope of 1 in 6 or 1/6
as for ramp
1
A
6
B

Fig. 1.

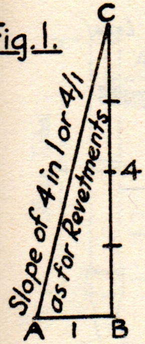

C
Slope of 4 in 1 or 4/1
as for Revetments
4
A
1
B

Fig. 3.

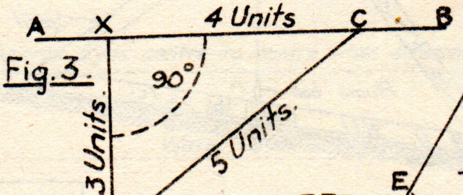

A
X
4 Units
C
B
90°
3 Units.
5 Units.
D

Fig. 5.

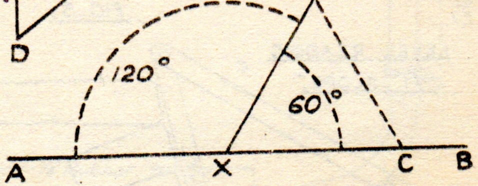
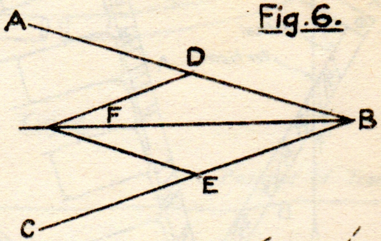

E
120°
60°
A
X
C
B

Fig. 6.



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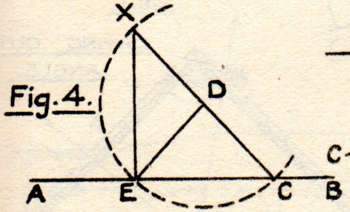

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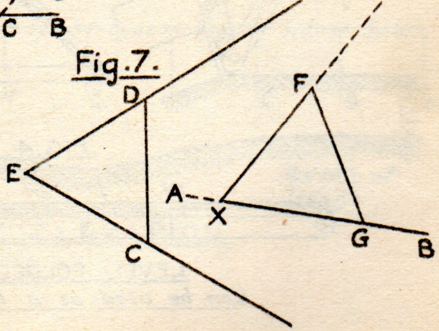

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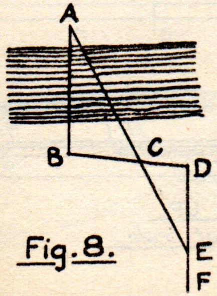


FIELD LEVEL.

FIG. 2.

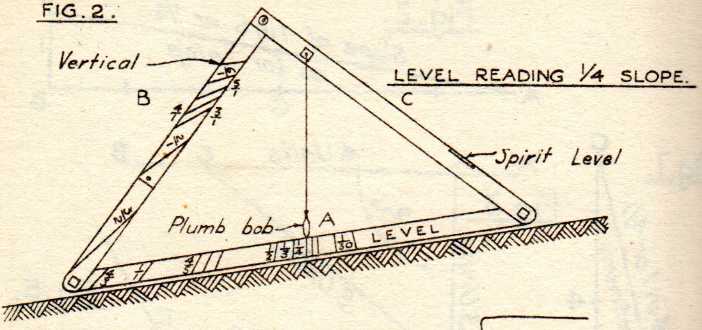

Vertical
B
C
LEVEL READING 1/4 SLOPE.
Spirit Level
Plumb bob
A
LEVEL
5/1
4/1
3/1
1/2
3/4
1/30

FIG. 3.

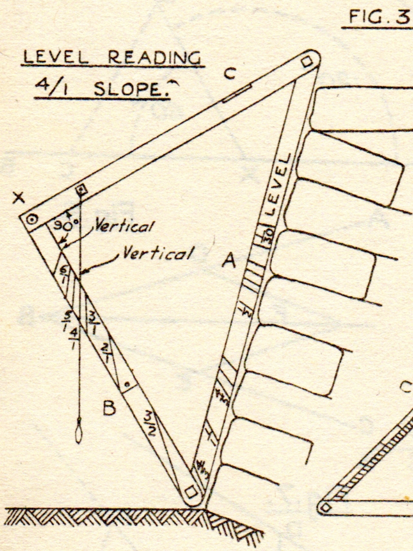

LEVEL READING 4/1 SLOPE.
C
X
90°
Vertical
Vertical
A
LEVEL
6/1
5/1
4/1
3/1
2/1
B
3/2
1/30

FIG. 1.

LAYING OUT ANGLE.

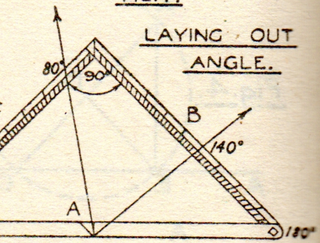
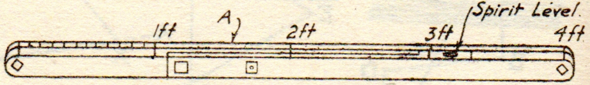

80°
90°
C
B
140°
A
180°

FIG. 4.


1ft
A
2ft
Spirit Level.
3ft
4ft

LEVEL FOLDED UP.
Can be used as a foot rule.

IMPROVISED LEVEL.

Fig. 1.

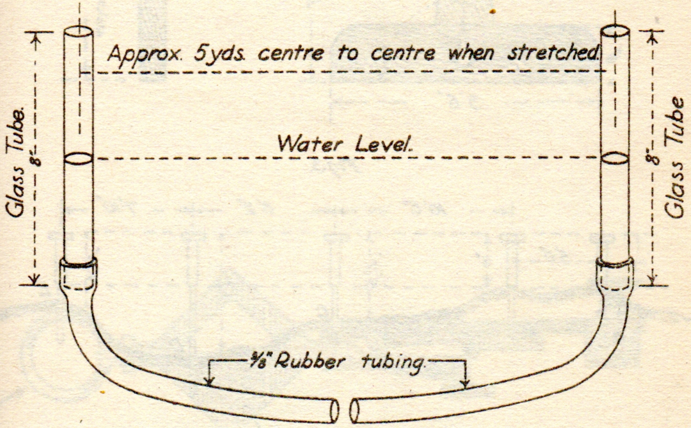
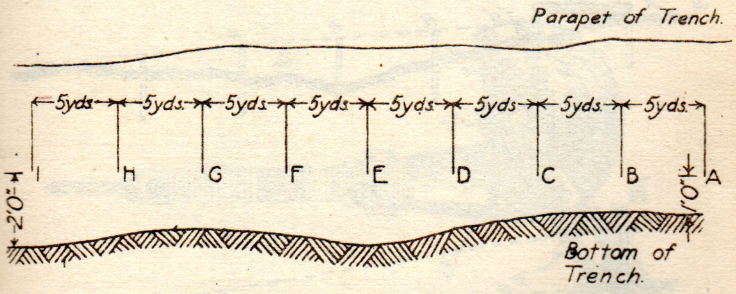

Approx. 5yds. centre to centre when stretched.
Glass Tube. 8"
Water Level.
Glass Tube 8"
3/8" Rubber tubing.

Fig. 2.


Parapet of Trench.
5yds.
5yds.
5yds.
5yds.
5yds.
5yds.
5yds.
5yds.
I
H
G
F
E
D
C
B
A
2'0"
1'0"
Bottom of Trench.

SIDE ELEVATION.

BONING AND LEVELLING.

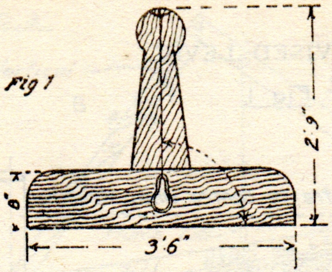


Fig 1

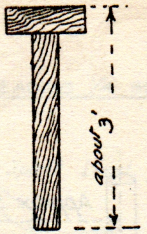


Fig 2

Fig 3

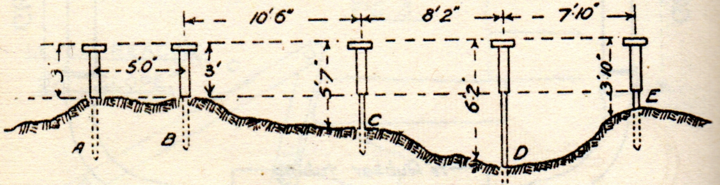

10'6"
8'2"
7'10"
3'
5'0"
3'
5'7"
6'2"
3'10"
A
B
C
D
E

Fig 4

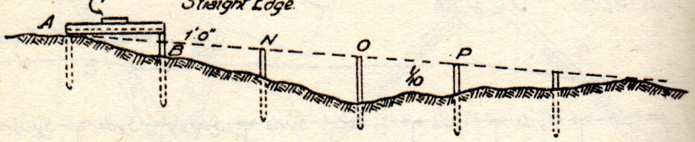
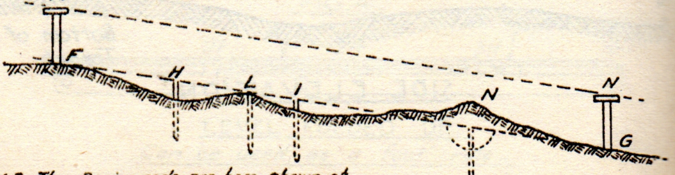

Spirit Level
Straight Edge
A
B
1'0"
N
O
P
1/10

Fig 5



N.B. The Boning rods are here shewn at right angles to their proper position

---

CLINOMETER, PENDENT (DE LISLE'S).

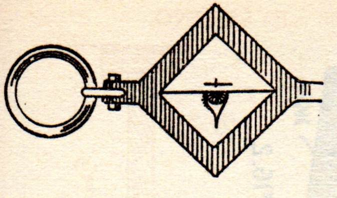


FIG. 2.

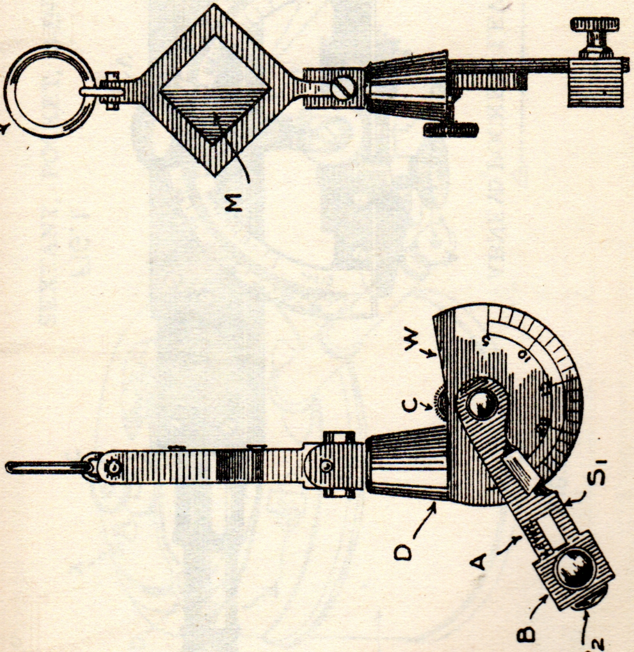

H
M
W
C
D
A
B
S1
S2

FIG. 1.

ABNEY POCKET LEVEL.

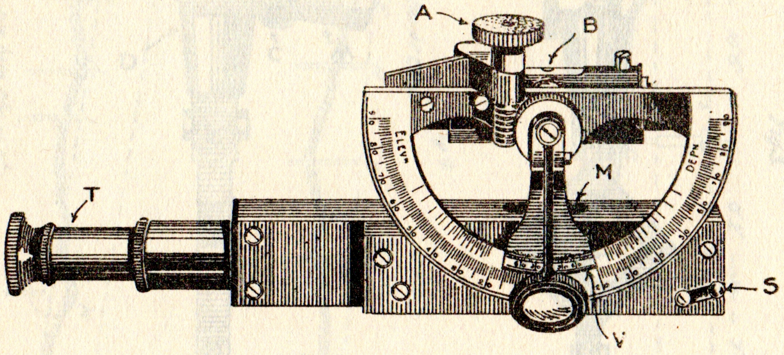

A
B
T
M
S
V
ELEVN
DEPN

FIG. 1.

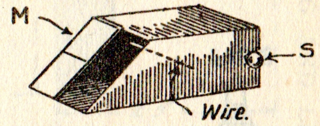


FIG. 2.

SEXTANT, POCKET, 3-IN.

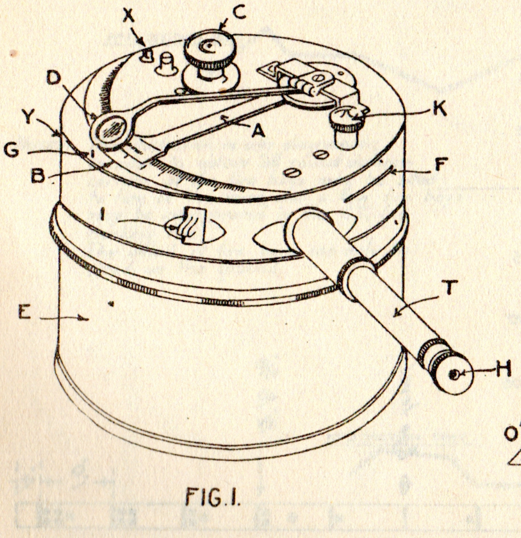

X
C
D
Y
G
B
A
K
F
I
E
T
H

FIG. 1.

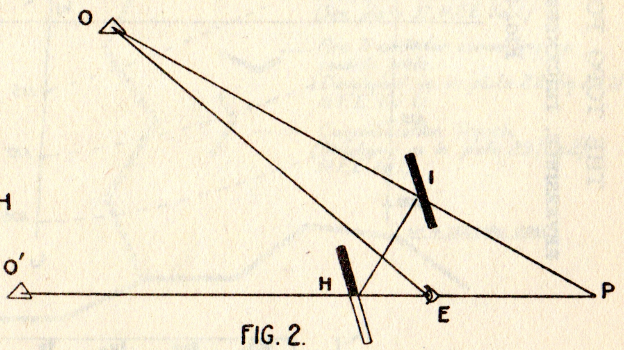


FIG. 2.

PLATE 8. [*Ref.* Sec. 6, 4.

THE TOPO POLE.

REVERSIBLE, THICKNESS ABOUT 5/8".

FIG. 2.

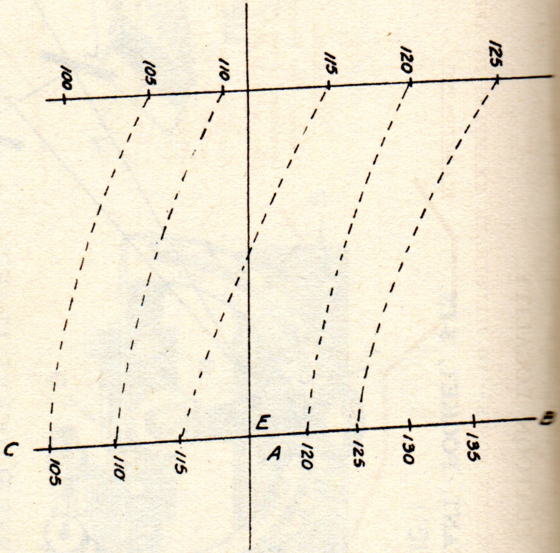
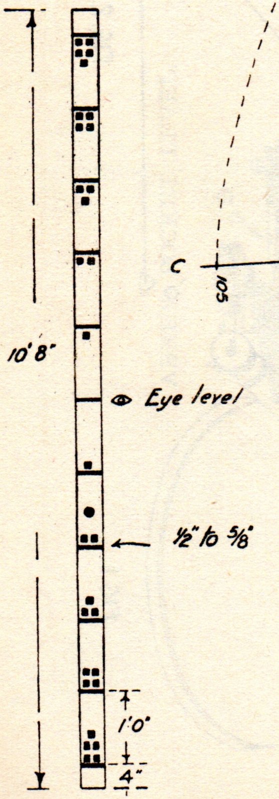

100
105
110
115
120
125
C
E
A
B
105
110
115
120
125
130
135

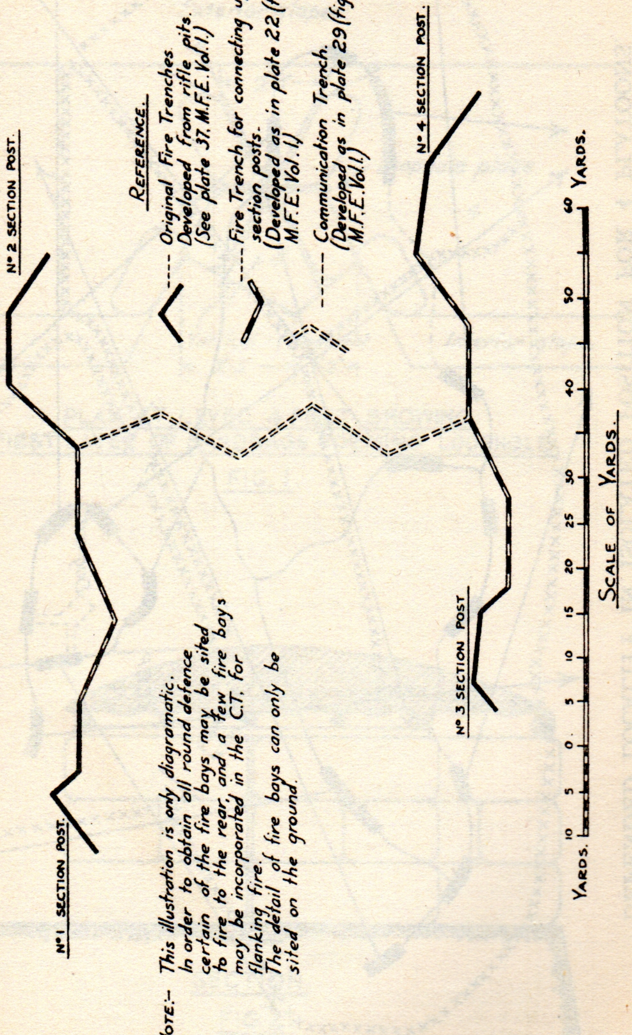
FIG. 1.


10' 8"
Eye level
1/2" to 5/8"
1' 0"
4"

Ref. Sec. 8, 2 *and Appendix* II.] **PLATE 9.**

A PLATOON LOCALITY.

SHOWING METHOD OF JOINING UP SECTION POSTS. TO ILLUSTRATE EXAMPLES IN APPENDIX II.

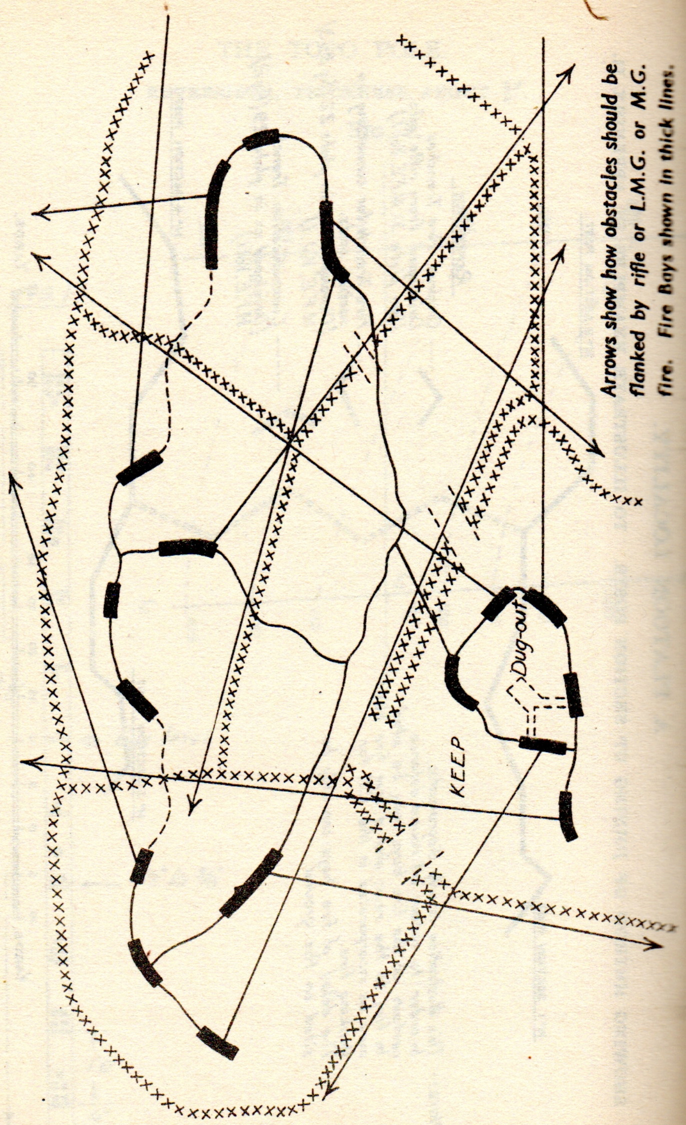

No. 1 SECTION POST.
No. 2 SECTION POST.
No. 3 SECTION POST.
No. 4 SECTION POST.
YARDS.
10
5
0
5
10
15
20
25
30
40
50
60
YARDS.
SCALE OF YARDS.

REFERENCE.

- Original Fire Trenches. Developed from rifle pits. (See plate 37. M.F.E. Vol. I.)
- Fire Trench for connecting up section posts. (Developed as in plate 22 (fig 2+3) M.F.E. Vol. I.)
- Communication Trench. (Developed as in plate 29 (fig. 2) M.F.E. Vol. I.)

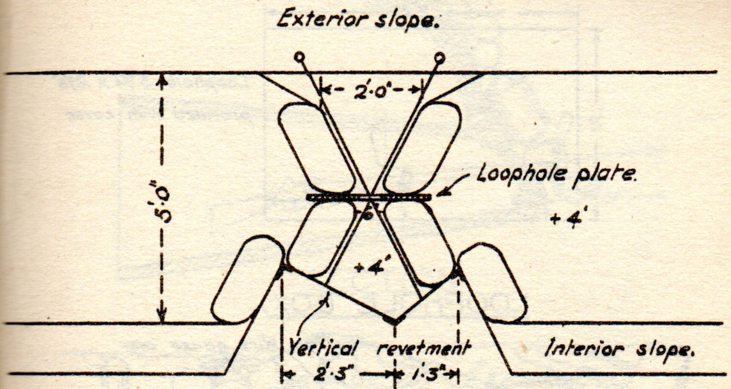
NOTE:– This illustration is only diagramatic. In order to obtain all round defence certain of the fire bays may be sited to fire to the rear, and a few fire bays may be incorporated in the C.T. for flanking fire. The detail of fire bays can only be sited on the ground.

DEFENDED LOCALITY IN ISOLATED POSITION FOR 4 PLATOONS.


Dug-out
KEEP

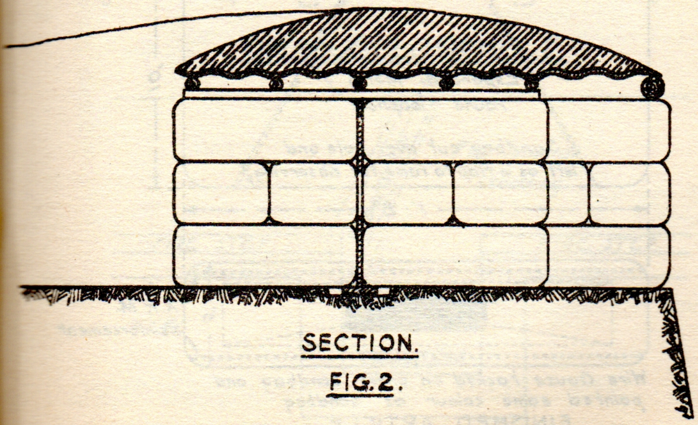
Arrows show how obstacles should be flanked by rifle or L.M.G. or M.G. fire. Fire Bays shown in thick lines.

LOOPHOLES.


Exterior slope.
2'0"
5'0"
Loophole plate.
+4'
+4'
+4'
Vertical revetment
2'3"
1'3"
Interior slope.

PLAN AT LEVEL 4 FEET SHOWING FIRST LAYER OF SANDBAGS FORMING LOOPHOLE.

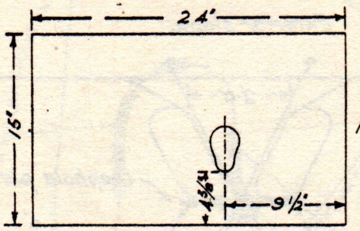
FIG. 1.



SECTION.

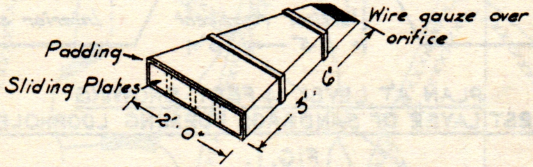
FIG. 2.

LOOPHOLE PLATE.


2' 4"
15"
4 3/8"
9 1/2"

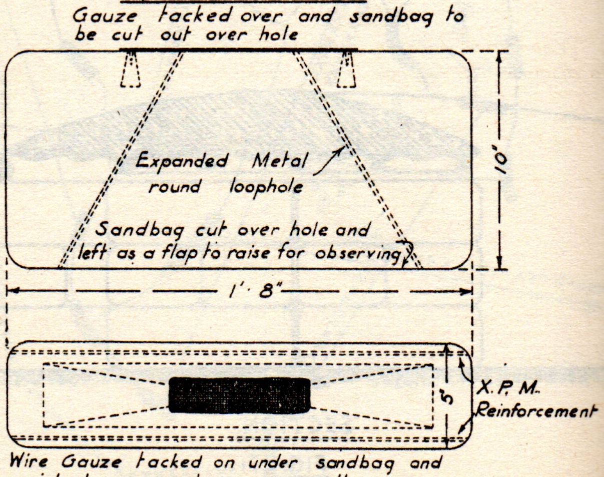
Loophole 3 3/4" x 2 1/8" provided with cover.

LOOPHOLE BOX.


Wire gauze over orifice
Padding
Sliding Plates
2' 0"
5' 6"

MOCK SANDBAG CEMENT LOOPHOLE.

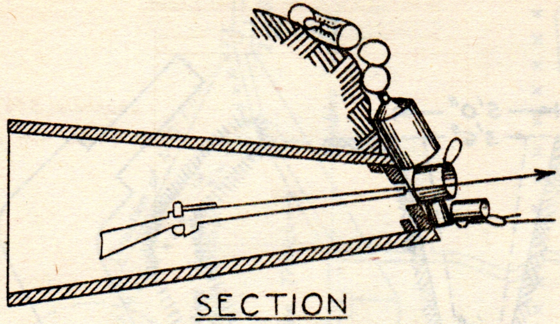
FOR OBSERVATION.


Gauze tacked over and sandbag to be cut out over hole
Expanded Metal round loophole
Sandbag cut over hole and left as a flap to raise for observing
10"
1' 8"
5"
X. P. M. Reinforcement

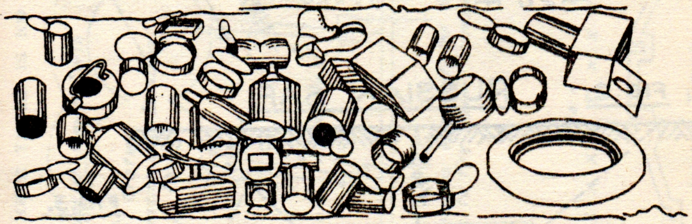
Wire Gauze tacked on under sandbag and painted same colour as sandbag

FINISHED ARTICLE

SNIPER'S POST.



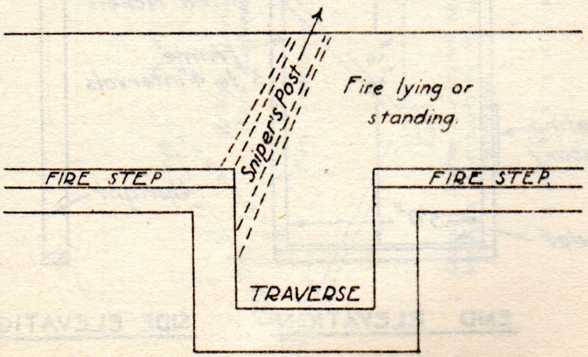
SECTION



VIEW FROM FRONT

When front parapet is covered with tins of all kinds, the tin used to disguise the loophole is very difficult to identify even at 10 yds. range.

OBLIQUE LOOPHOLE.


Sniper's Post
Fire lying or standing.
FIRE STEP
FIRE STEP
TRAVERSE

Plenty of Dummy Loopholes should be provided.

SAPPING.

FIG. 1.

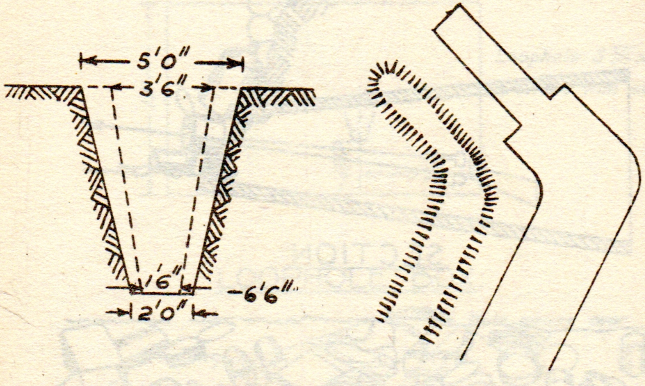
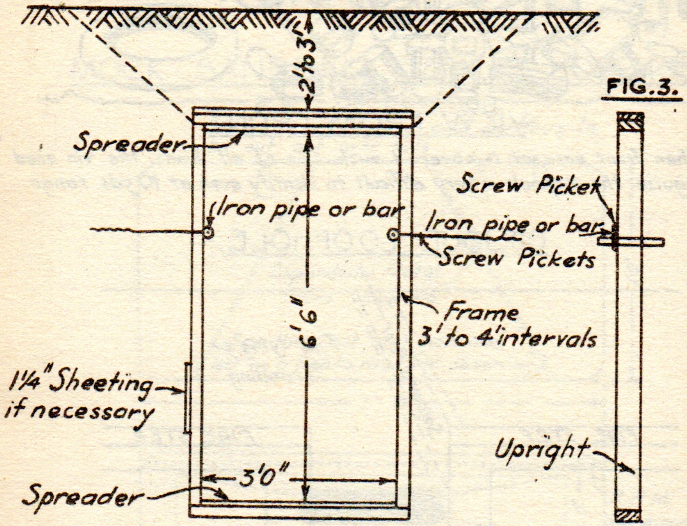

5'0"
3'6"
1'6"
2'0"
6'6"

FIG. 2. RUSSIAN SAP.

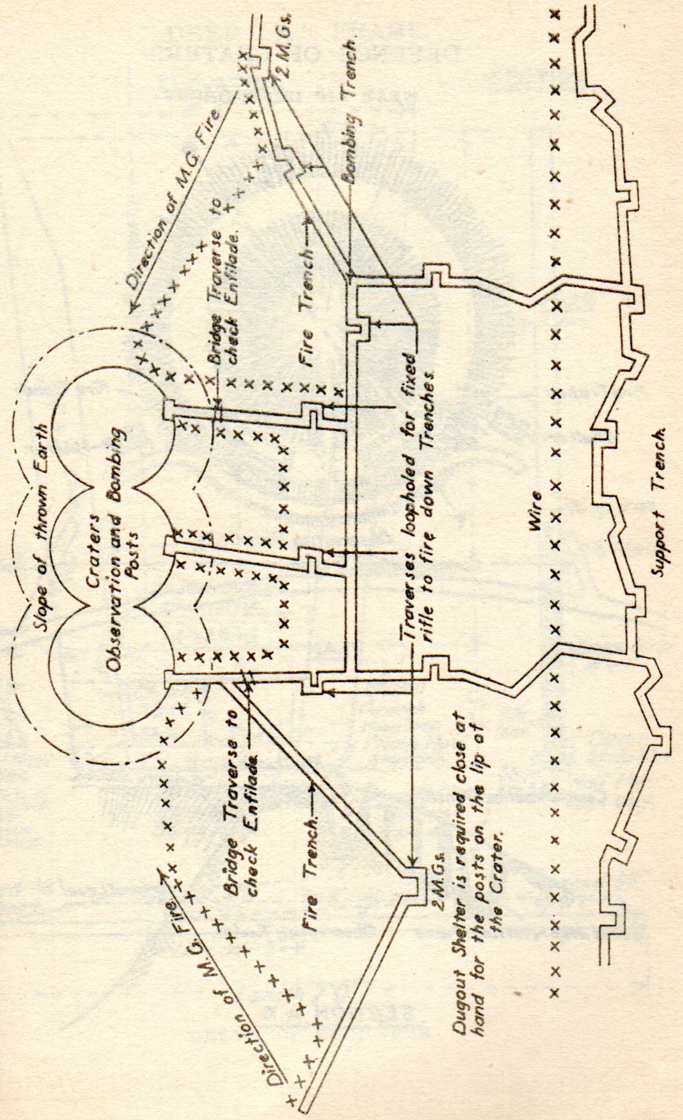
FIG. 3.


2' to 3'
Spreader
Iron pipe or bar
Iron pipe or bar
Screw Picket
Screw Pickets
6'6"
Frame 3' to 4' intervals
1¼" Sheeting if necessary
Upright
3'0"
Spreader

END ELEVATION SIDE ELEVATION.

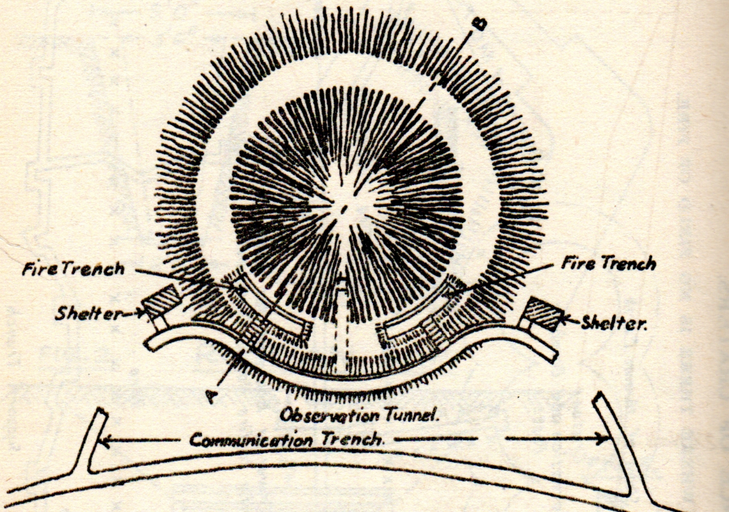
DEFENCE OF CRATERS.

BY BOMBING TRENCHES WHERE THERE IS NO FIELD OF FIRE.

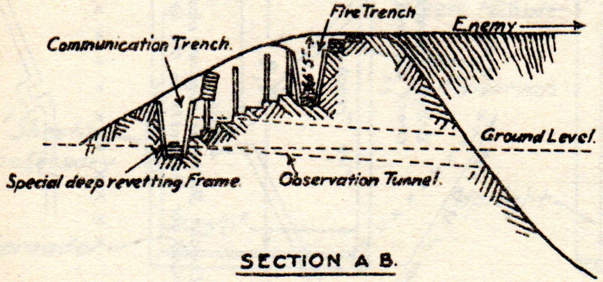

2 M.Gs.
Direction of M.G. Fire
Bombing Trench.
Bridge Traverse to check Enfilade.
Fire Trench.
Slope of thrown Earth
Craters Observation and Bombing Posts
Traverses loopholed for fixed rifle to fire down Trenches
Wire
Support Trench.
Bridge Traverse to check Enfilade.
Fire Trench.
2 M.Gs.
Direction of M.G. Fire.
Dugout Shelter is required close at hand for the posts on the lip of the Crater.

DEFENCE OF CRATERS.

NEAR LIP DEFENDED.

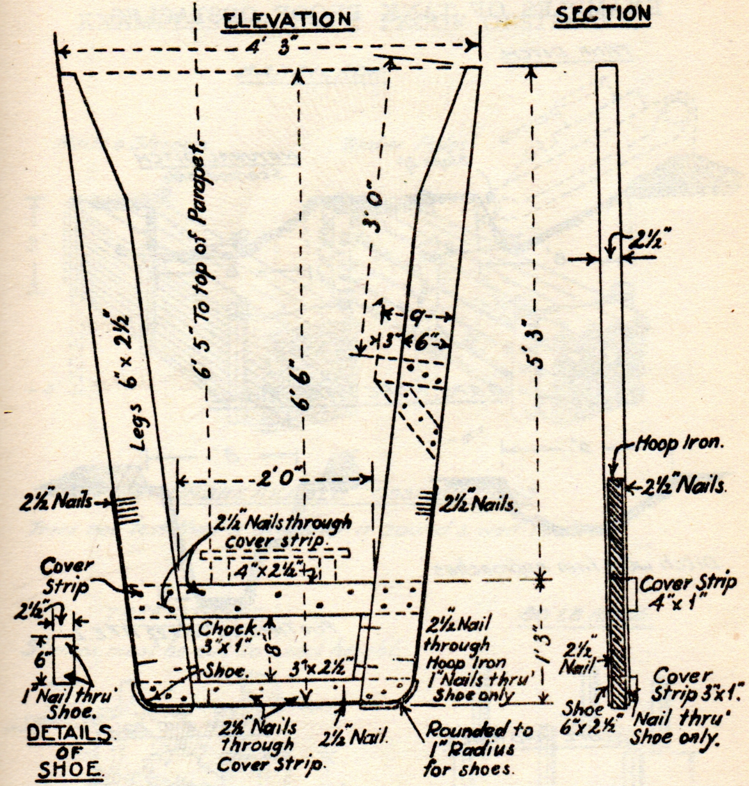

B
Fire Trench
Fire Trench
Shelter
Shelter.
A
Observation Tunnel.
Communication Trench.

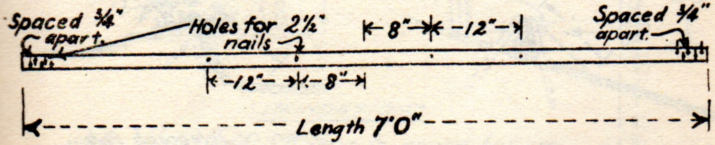
PLAN


Fire Trench
Enemy
Communication Trench.
5'
Ground Level.
Special deep revetting Frame
Observation Tunnel.

SECTION A B.

DEEP "A" FRAME.

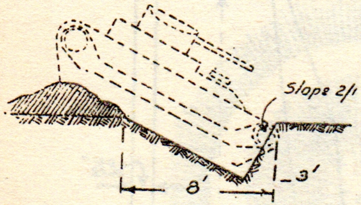

ELEVATION
SECTION
4' 3"
6' 5" To top of Parapet.
6' 6"
3' 0"
5' 3"
1' 3"
Legs 6"x 2½"
9"
3" 6"
2' 0"
2½" Nails
2½" Nails.
2½" Nails through cover strip.
4"x 2½"
Cover Strip
Chock. 3"x 1"
8"
Shoe.
3"x 2½"
2½" Nail through Hoop Iron 1" Nails thru' Shoe only
2½"
6"
1" Nail thru' Shoe.
DETAILS OF SHOE.
2½" Nails through Cover Strip.
2½" Nail.
Rounded to 1" Radius for shoes.
2½"
Hoop Iron.
2½" Nails.
Cover Strip 4"x 1"
2½" Nail.
Cover Strip 3"x 1".
Shoe 6"x 2½"
Nail thru' Shoe only.


Spaced ¾" apart.
Holes for 2½" nails
8"
12"
Spaced ¾" apart.
12"
8"
Length 7' 0"

DETAIL OF HOOP IRON.

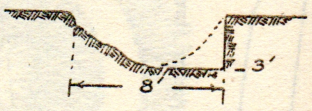
EXAMPLES OF TANK PROOF OBSTACLES.

TANK DITCH.

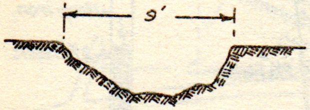


NATURAL DITCH.

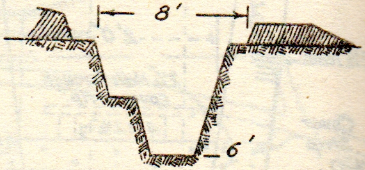
Scarped side



GAPS MORE THAN 8' WIDE.

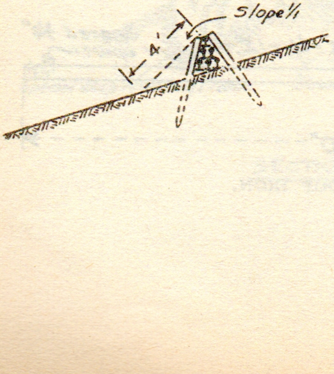


Ditch with firm approaches.

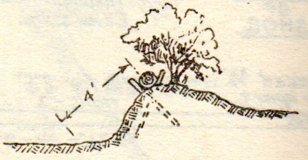


Fire Trench. Plate 22 M.F.E.I.

SLOPE AND RAILS.



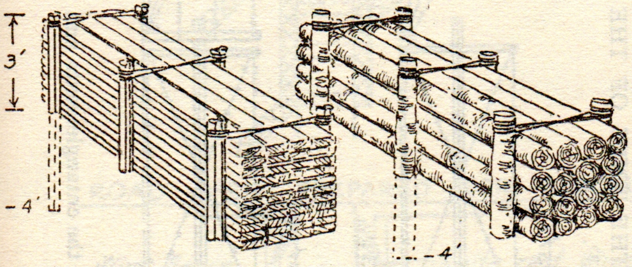
BANK AND POLE.



Spar or Telegraph Pole.

EXAMPLES OF TANK PROOF OBSTACLES.

BARRICADE


Rails & Sleepers

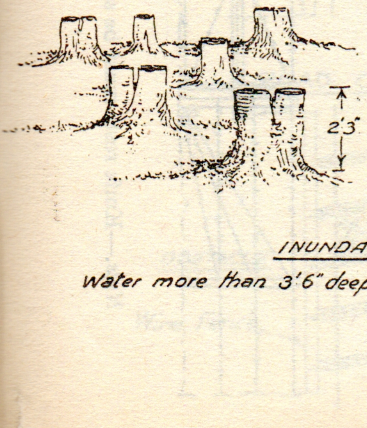
Timber Poles

UNBREAKABLE OBSTRUCTIONS

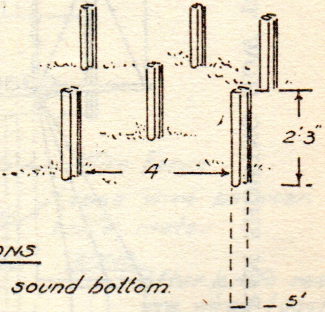
Trees not less than 9" Diameter if sound & well rooted.

TREE STUMPS

Stumps must be cut to exact height.



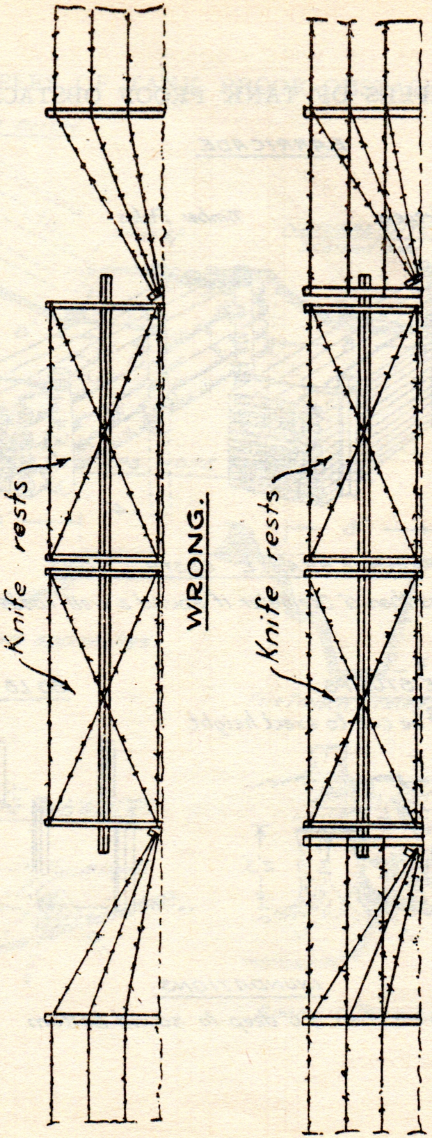
80 LB RAILS.



INUNDATIONS

Water more than 3'6" deep to sound bottom.

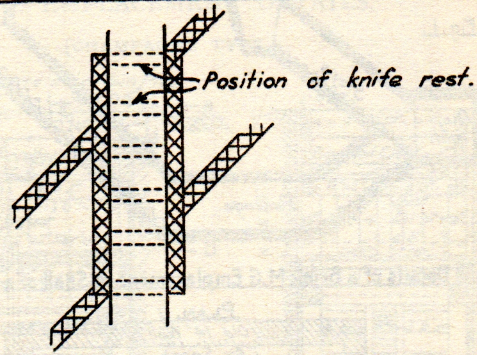
DIAGRAM SHOWING HOW TO FINISH OFF THE ENDS OF THE ENTANGLEMENT OF A GAP.


Knife rests
WRONG.
Knife rests
RIGHT.

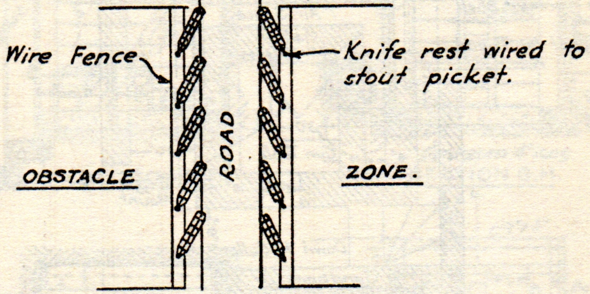
Note.—Knife rests must be securely anchored to the entanglements and to each other.

BLOCKING OF ROADS.

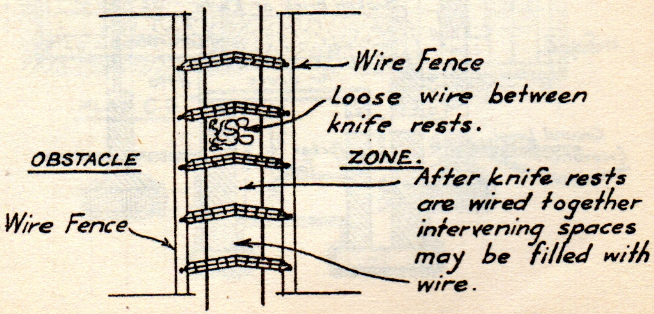
TWO BELTS OF WIRE CROSSING A ROAD DIAGONALLY.


Position of knife rest.

ROAD OPEN PREPARED FOR BLOCKING.


Wire Fence
Knife rest wired to stout picket.
ROAD
OBSTACLE
ZONE.

ROAD CLOSED.


Wire Fence
Loose wire between knife rests.
OBSTACLE
ZONE.
After knife rests are wired together intervening spaces may be filled with wire.
Wire Fence

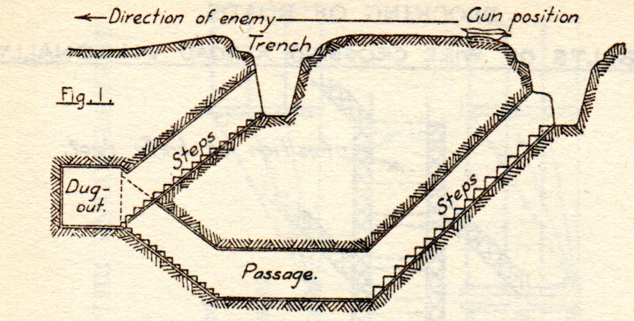

← Direction of enemy
Gun position
Trench
Steps
Dug-out.
Steps
Passage.

Fig. 1.

Details of a Brick M.G Emplacement in Shell of a House.

PLAN.

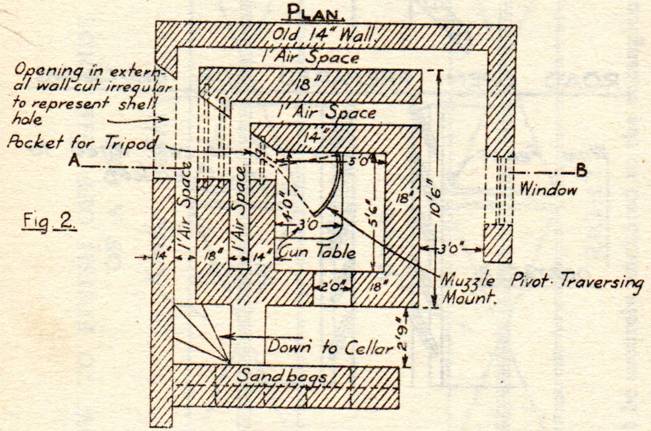

Old 14" Wall
1' Air Space
18"
1' Air Space
14"
Opening in external wall cut irregular to represent shell hole
Pocket for Tripod
A
B
Window
1' Air Space
1' Air Space
5'0"
4'0"
3'0"
5'6"
18"
10'6"
14"
18"
14"
Gun Table
3'0"
Muzzle Pivot Traversing Mount.
2'0"
18"
2'9"
Down to Cellar
Sandbags

Fig. 2.

SECTION A.B.

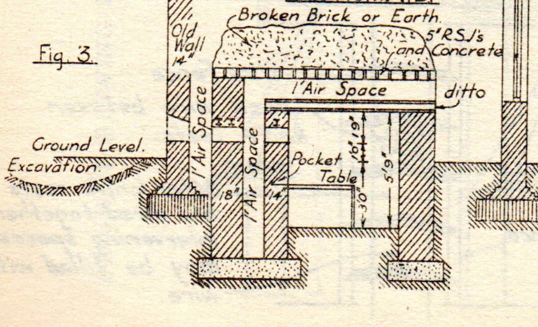
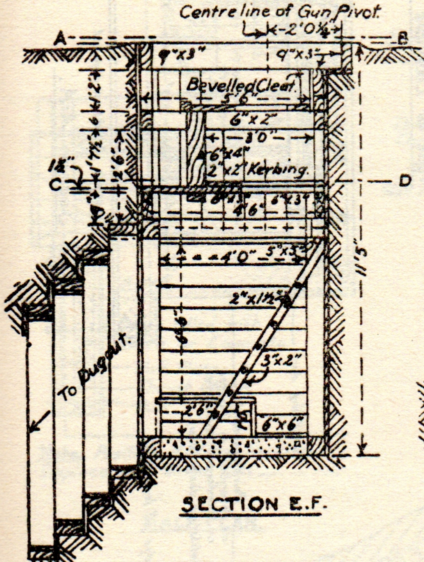

Broken Brick or Earth.
5" R.S.J's and Concrete
Old Wall 14"
1' Air Space
ditto
1' Air Space
1' Air Space
Ground Level.
Excavation
Pocket
Table
18"
14"
1'6"
1'9"
5'9"
3'0"

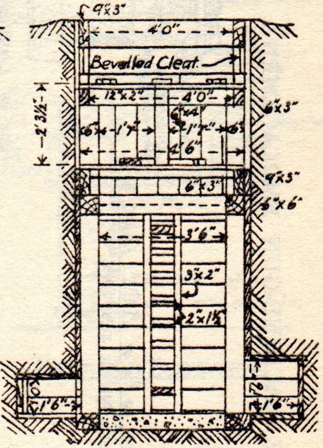
Fig. 3.

M.G. EMPLACEMENT DETAILS.

(CHAMPAGNE TYPE.)

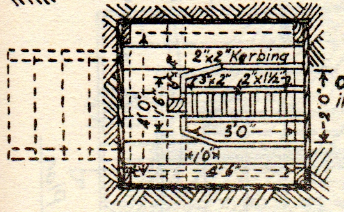

Centre line of Gun Pivot.
2'0½"
A
B
9"×3"
9"×3"
Bevelled Cleat
5'6"
6"×2"
3'0"
6"×4"
2"×2" Kerbing.
C
D
1½"
4'6"
6"×3"
4'0"
5"×3"
2"×1½"
3"×2"
2'6"
6"×6"
11'5"
To Dugout.

SECTION E.F.

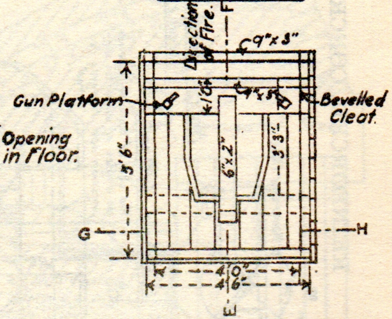

9"×3"
4'0"
Bevelled Cleat.
12"×2"
4'0"
6"×4"
1'7"
4'6"
2'3½"
6"×3"
9"×3"
6"×6"
3'6"
3"×2"
2"×1½"
1'6"
1'6"

Gun Recess 4" long.

SECTION G.H.


2"×2" Kerbing
3"×2"
2"×1½"
3'0"
1'0"
4'6"
4'0"
2'0"
Opening in Floor.

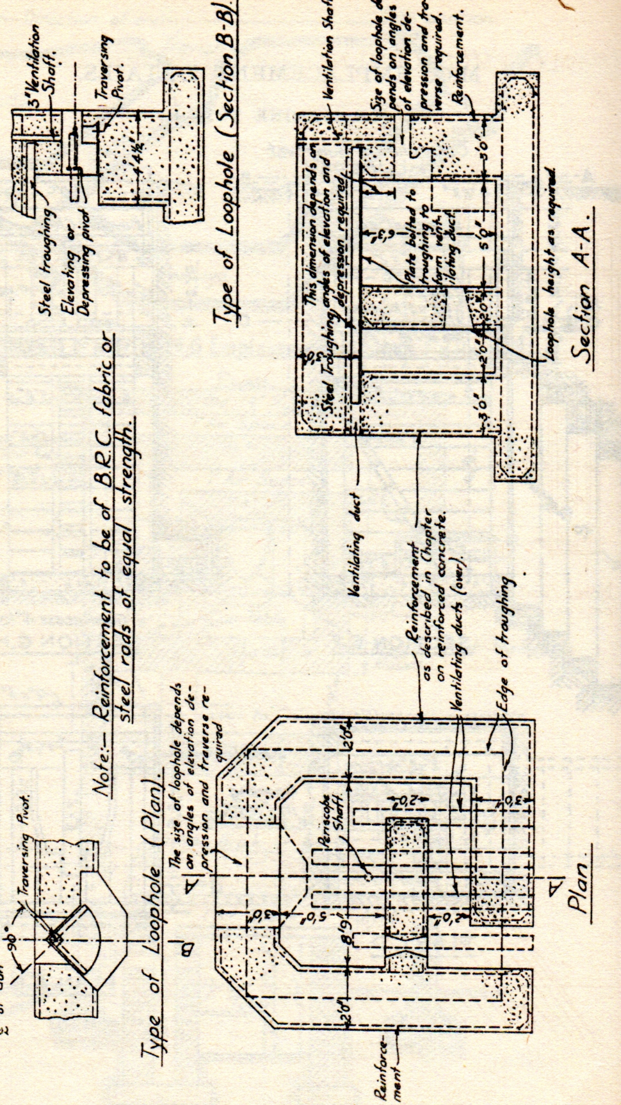
PLAN C.D.


Direction of Fire.
F
9"×3"
Gun Platform
Bevelled Cleat.
1'6"
4"×5"
6"×2"
3'3"
5'6"
G
H
4'0"
4'6"
E

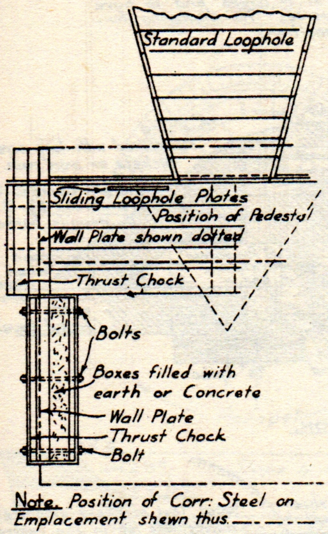
PLAN A.B.

REINFORCED CONCRETE MACHINE-GUN EMPLACEMENT.

Note:— Reinforcement to be of B.R.C. fabric or steel rods of equal strength.

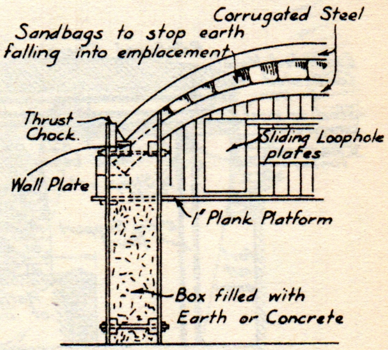

3" Ventilation Shaft.
Traversing Pivot.
4'4½"
Steel troughing
Elevating or Depressing pivot
Type of Loophole (Section B-B).
Ventilation Shaft.
Size of loophole depends on angles of elevation depression and traverse required.
Reinforcement.
This dimension depends on angles of elevation and depression required.
Steel Troughing
Plate bolted to troughing to form ventilating duct.
6'3"
3'0"
5'0"
2'0"
Loophole height as required.
Section A-A.
Ventilating duct
Reinforcement as described in Chapter on reinforced concrete.
Ventilating ducts (over).
Edge of troughing
℄ of Gun
90°
Traversing Pivot.
B
B
Type of Loophole (Plan).
The size of loophole depends on angles of elevation depression and traverse required.
A
A
Periscope Shaft.
2'0"
3'0"
5'0"
8'9"
2'0"
Plan.
Reinforcement

M.G. EMPLACEMENT, BREASTWORK PATTERN.

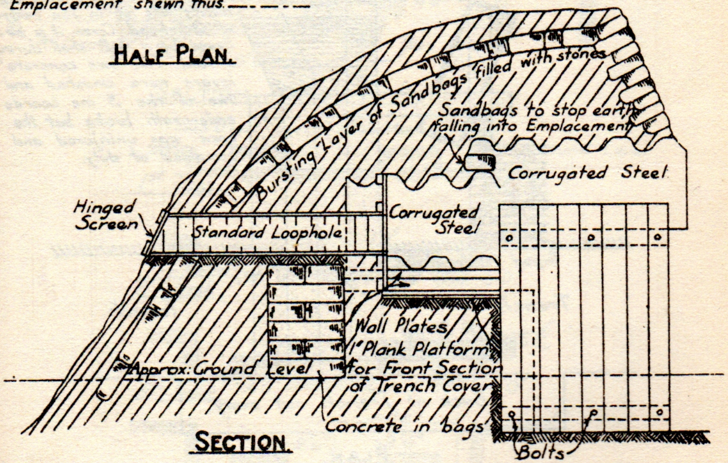

Standard Loophole
Sliding Loophole Plates
Position of Pedestal
Wall Plate shown dotted
Thrust Chock
Bolts
Boxes filled with earth or Concrete
Wall Plate
Thrust Chock
Bolt

Note. Position of Corr: Steel on Emplacement shewn thus._ . _ . _

HALF PLAN.


Corrugated Steel
Sandbags to stop earth falling into emplacement
Thrust Chock.
Wall Plate
Sliding Loophole plates
1" Plank Platform
Box filled with Earth or Concrete

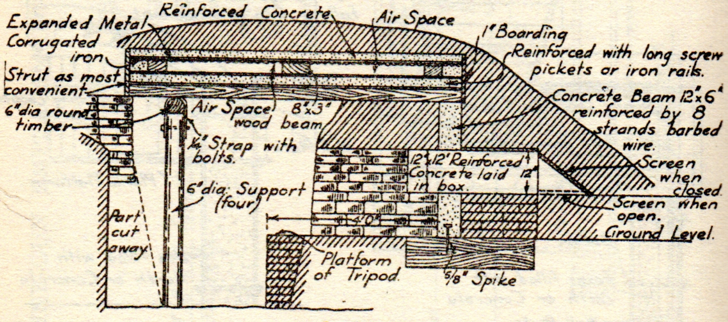
HALF END ELEVATION.


Bursting Layer of Sandbags filled with stones
Sandbags to stop earth falling into Emplacement
Corrugated Steel
Hinged Screen
Standard Loophole
Corrugated Steel
Wall Plates
1" Plank Platform for Front Section of Trench Cover
Approx: Ground Level
Concrete in bags
Bolts

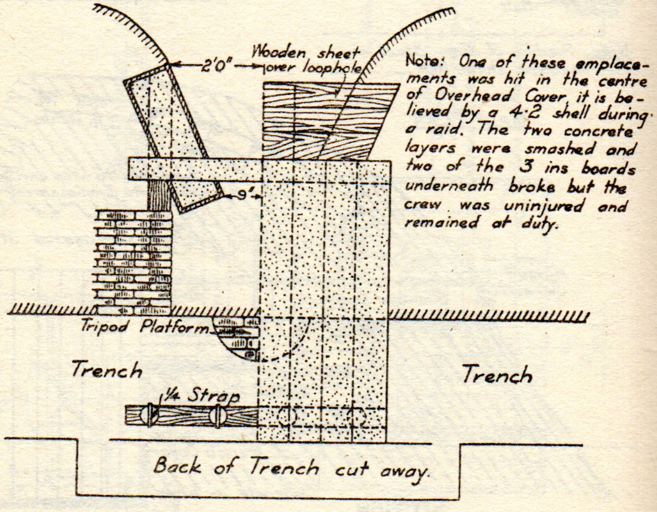
SECTION.

MACHINE-GUN EMPLACEMENT.

Designed for construction in 4 hours and to have the appearance of a Traverse. The shuttering for the concrete is left in position.


Expanded Metal
Corrugated iron
Reinforced Concrete
Air Space
1" Boarding
Reinforced with long screw pickets or iron rails.
Strut as most convenient
6"dia round timber
Air Space
8"x3" wood beam
Concrete Beam 12"x6" reinforced by 8 strands barbed wire.
¼" Strap with bolts.
12"x12" Reinforced Concrete laid in box.
12"
Screen when closed.
6"dia. Support (four)
4'0"
Screen when open.
Ground Level.
Part cut away.
Platform of Tripod.
5/8" Spike

SECTION.

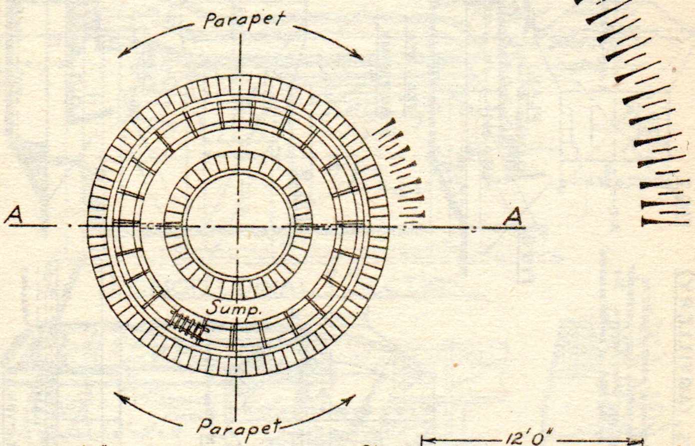

2'0"
Wooden sheet over loophole
9"
Tripod Platform
Trench
Trench
¼ Strap
Back of Trench cut away.

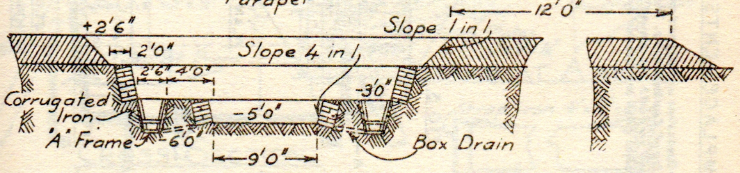
Note: One of these emplacements was hit in the centre of Overhead Cover, it is believed by a 4·2 shell during a raid. The two concrete layers were smashed and two of the 3 ins boards underneath broke but the crew was uninjured and remained at duty.

PLAN.

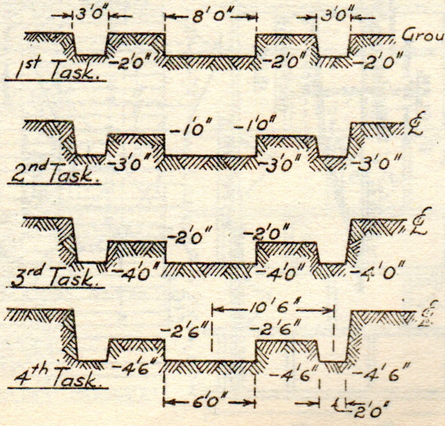
EMPLACEMENT FOR SHORT ARM H.C.D. PROJECTOR.

▨ *Made Earth.* ▩ *Natural Soil.*


Parapet
A
A
Sump.
Parapet


+2'6"
2'0"
12'0"
Slope 1 in 1,
Slope 4 in 1,
2'6"
4'0"
-3'0"
Corrugated Iron
-5'0"
"A" Frame
-6'0"
9'0"
Box Drain

SECTION THRO' A·A.


3'0"
8'0"
3'0"
Ground Level.
1st Task.
-2'0"
-2'0"
-2'0"
-1'0"
-1'0"
2nd Task.
-3'0"
-3'0"
-3'0"
℄
-2'0"
-2'0"
3rd Task.
-4'0"
-4'0"
-4'0"
℄
10'6"
-2'6"
-2'6"
4th Task.
-4'6"
-4'6"
-4'6"
6'0"
2'0"
℄

EMPLACEMENTS, (ARTILLERY)

These Dimensions are suggested as a general guide to the size of Emplacements. The details in any particular case will vary with the ground and other factors. The Dimensions given are governed by the angle of switch assumed.

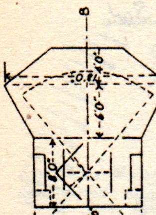

B
A
PLAN
Allows 80° switch
4'0"
6'0"

FIG. 7.

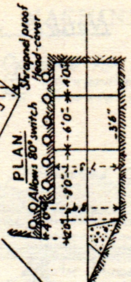

Shrapnel proof Head-cover
4'0"
6'0"
SECTION A.B
60 PDR MK. I

FIG. 8.

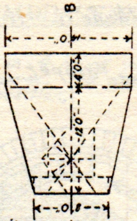

B
A
PLAN
Allows 70° switch
4'0"
12'0"

FIG. 9.

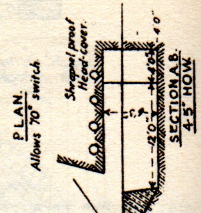

Shrapnel proof Head-cover
4'0"
12'0"
SECTION A.B
4·5" HOW.

FIG. 10.

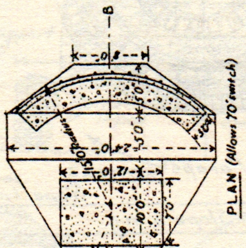

B
A
PLAN (Allows 70° switch)
Radius
5'0"
10'0"

FIG. 5.

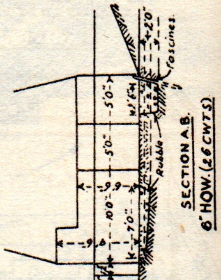

Fascines
Rubble
5'0"
10'0"
SECTION A.B.
6" HOW. (26 CWTS)

FIG. 6.

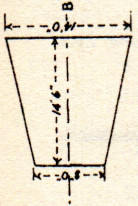


FIG. 1.

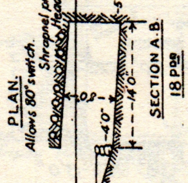

PLAN
Allows 80° switch
Shrapnel proof Head-cover
4'0"
14'0"
5'0"
SECTION A.B.
18 PDR

FIG. 2.

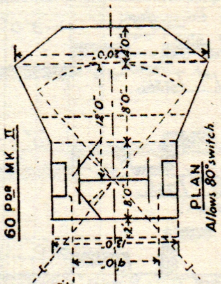

B
A
12'0"
8'0"
60 PDR MK. II

FIG. 3.

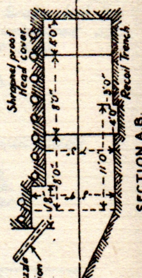
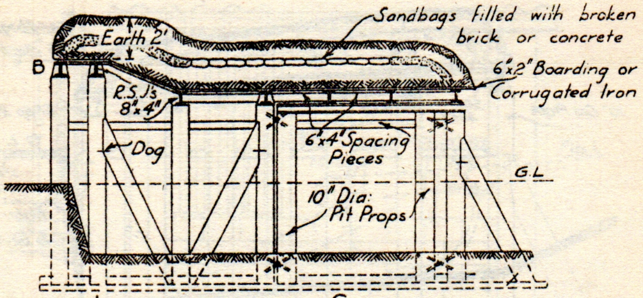

PLAN
Allows 80° switch
Shrapnel proof Head cover
Position of muzzle at 35° Elevation
8'0"
11'0"
5'0"
Recoil Trench
SECTION A.B.

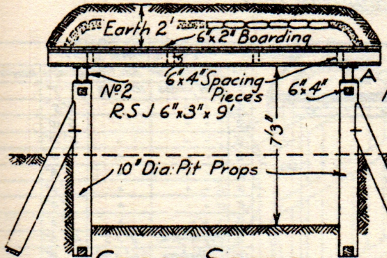
FIG. 4.

60-PR. GUN EMPL. WITH GIRDERS.

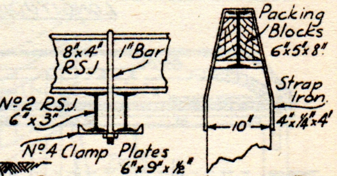
(SPLINTER PROOF.)


Sandbags filled with broken brick or concrete
Earth 2'
6"x2" Boarding or Corrugated Iron
B
R.S.J's 8"x4"
Dog
6"x4" Spacing Pieces
G.L
10" Dia: Pit Props

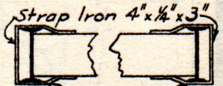
LONGITUDINAL SECTION.


Earth 2'
6"x2" Boarding
6"x4" Spacing Pieces
6"x4"
A
No2 R.S.J 6"x3"x 9'
7'3"
10" Dia: Pit Props

CROSS SECTION.

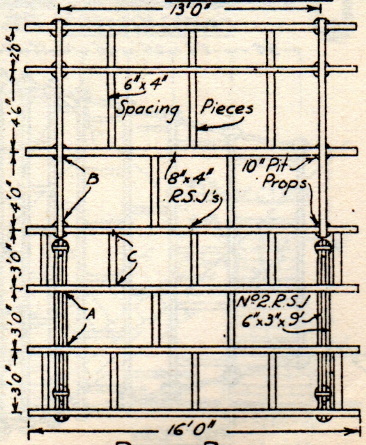

8"x4" R.S.J
1" Bar
No2 R.S.J. 6"x3"
No4 Clamp Plates 6"x9"x½"
Packing Blocks 6"x5"x8"
Strap Iron
10"
4"x¼"x4'

DETAILS AT A AND B.


Strap Iron 4"x¼"x3"

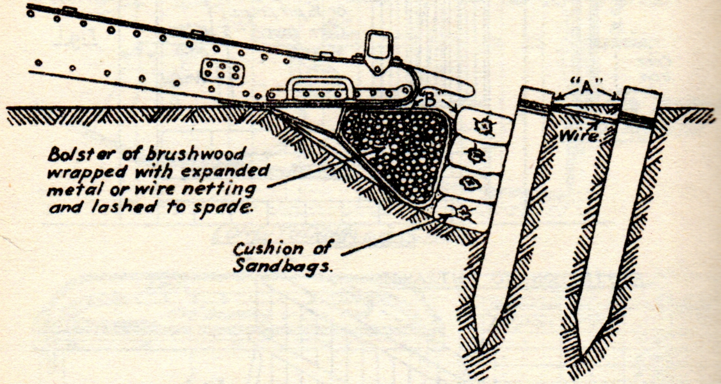
DETAIL AT C.

MATERIAL LIST.				
No	DESCRIPTION.	SECTION	LENGTH	REMARKS.
7	R.S. JOIST.	8"x4"	16'0".	
4	-do-	6"x3"	9'0"	
6	TIMBERS.	10" Round	8'3"	
4	"	"	8'8"	
4	"	"	10'3"	
14	"	"	7'6"	
2	"	9"x3"	24'0"	
2	"	6"x4"	6'0"	
4	"	"	3'3"	
2	"	"	1'2"	
2	"	"	3"	
3	"	"	4'6"	
2	"	"	4'0"	
14	"	"	3'0"	
3	"	"	2'0"	
32	"	6"x2"	20'6"	
2	"	9"x3"	20'6"	
4	CLAMP PLATES.	6"x9"x½"		Holed twice 1½" dia
8	NUTS	1⅛" thread		
38	STRAP IRON	4"x¼"	3'0"	
8	" "	4"x¼"	3'4"	
12	TIMBER PACKING BLOCKS	6"x5"x8"		SPLAYED.
72	NAILS.		6"	
220	"		4"	
16	DOGS		1'6"	
4	STRAP IRON	4"x¼"	3'2"	
4	TIMBER PACKING BLOCKS	4"x3"		
8	"	6"x3"x2"		
24	DOGS		12"	
4	IRON ROUND	1" DIA	3'6"	Threaded 6"

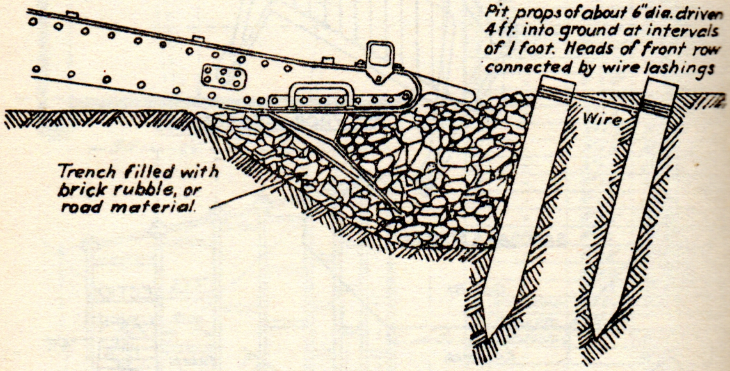

13'0"
2'6"
4'6"
4'0"
3'0"
3'0"
3'0"
6"x4" Spacing Pieces
B
8"x4" R.S.J's
10" Pit Props
C
A
No2 R.S.J 6"x3"x 9'
16'0"

ROOF PLAN.

TRAIL-SUPPORT SHOWING FIXED SUPPORT AT "A" AND CUSHION AT "B."

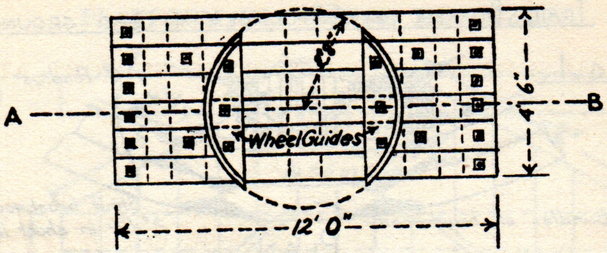

"A"
B
Wire
Bolster of brushwood wrapped with expanded metal or wire netting and lashed to spade.
Cushion of Sandbags.

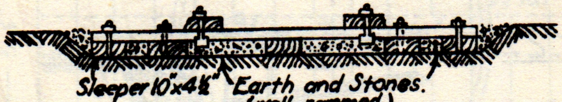
ALTERNATIVE DESIGN WITHOUT BOLSTER.


Pit props of about 6" dia. driven 4 ft. into ground at intervals of 1 foot. Heads of front row connected by wire lashings
Wire
Trench filled with brick rubble, or road material.

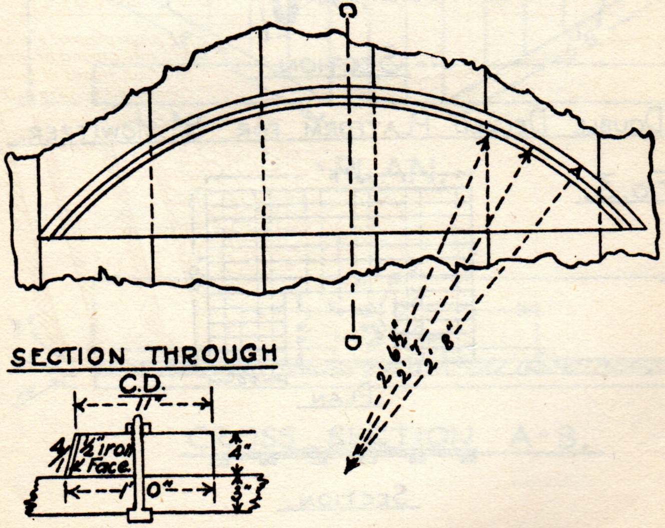
WOODEN WHEEL BED AND WHEEL GUIDES.

FOR CARRIAGE, FIELD, B.L. 60-PR. MK. IV.


A
B
6'
4' 6"
Wheel Guides
12' 0"


Sleeper 10"×4½"
Earth and Stones. (well rammed.)

SECTION THROUGH A.B.


C
D
2' 6½"
2' 7"
2' 8"
11"
4"
½" iron Face.
4
1' 0"
3"

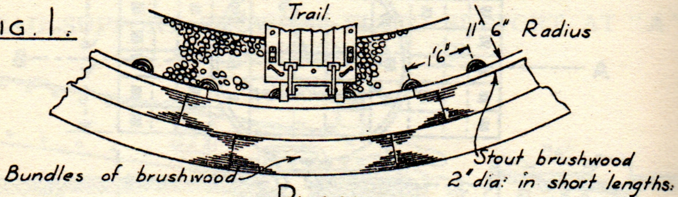
SECTION THROUGH C.D.

ENLARGED PLAN AND SECTION OF WHEEL GUIDES.

GUN PLATFORMS.

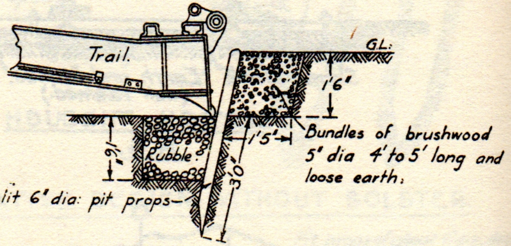
TRAIL BUFFER FOR 60 POUNDER IN BAD GROUND.

FIG. 1.


Trail.
11' 6" Radius
1'6"
Bundles of brushwood
Stout brushwood
2" dia: in short lengths.

PLAN.

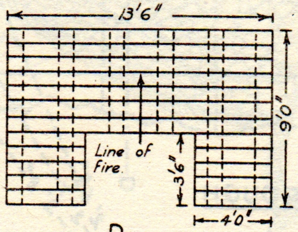
FIG. 2.


Trail.
G.L.
1'6"
Rubble.
1'6"
1'5"
3'0"
Bundles of brushwood
5' dia 4' to 5' long and
loose earth.
Split 6" dia: pit props

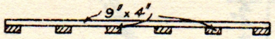
SECTION.

DOUBLE DECKED PLATFORM FOR 8" HOWITZER.

FIG. 3.

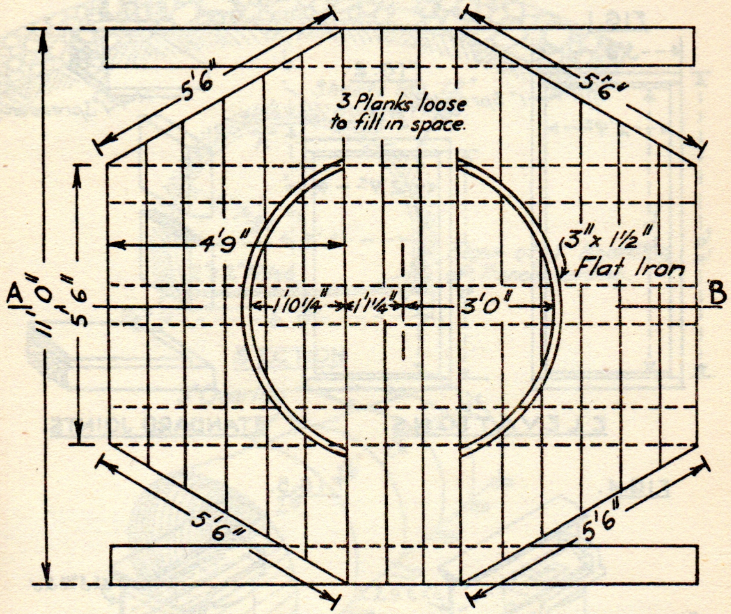

13'6"
9'0"
Line of
Fire.
3'6"
4'0"

PLAN.

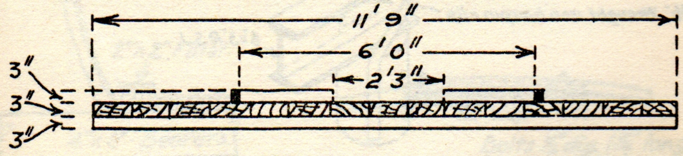


SECTION.

PLATFORM FOR 6-INCH HOWITZER.


5'6"
5'6"
3 Planks loose
to fill in space.
4'9"
3" x 1½"
Flat Iron
A
B
11'0"
5'6"
1'10¼"
1'1¼"
3'0"
5'6"
5'6"

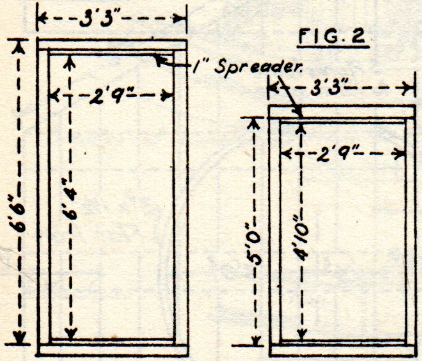
PLAN.


11'9"
6'0"
2'3"
3"
3"
3"

CROSS SECTION A-B.

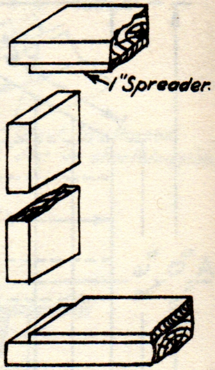
STANDARD SETTS AND CLIPS 3" TIMBER.

FIG. 1. FIG. 2


3'3"
1" Spreader.
2'9"
6'6"
6'4"
3'3"
2'9"
5'0"
4'10"

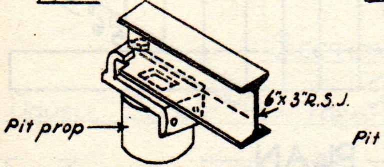
ELEVATIONS.

FIG. 3.



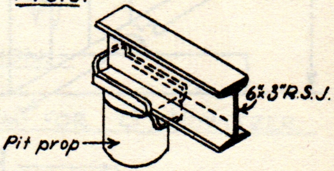
STANDARD JOINTS.

FIG. 4.


6"x 3" R.S.J.
Pit prop

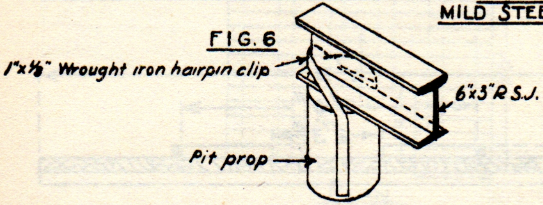
DETAIL OF MILD STEEL Z SHOE.

FIG. 5.


6"x 3" R.S.J.
Pit prop

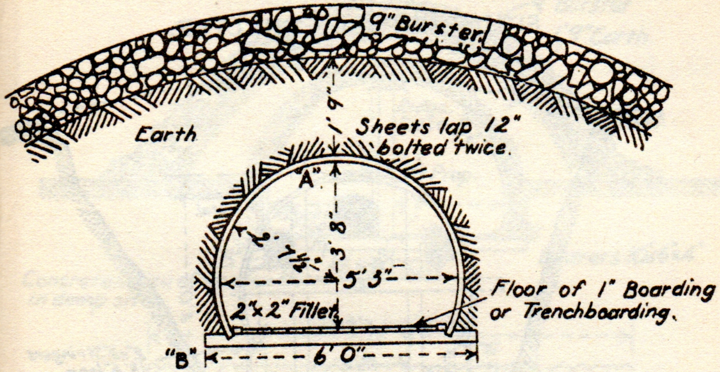
DETAIL OF MILD STEEL SHOE MK II

FIG. 6

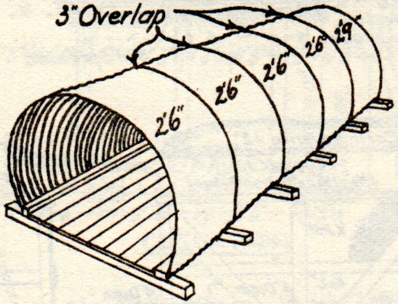

1"x ⅛" Wrought iron hairpin clip
6"x 3" R.S.J.
Pit prop

DETAIL OF HAIRPIN CLIP.

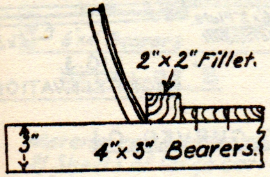
SMALL CORRUGATED STEEL SHELTER.


9" Burster.
Earth
1' 9"
Sheets lap 12" bolted twice.
"A"
2' 7½"
3' 8"
5' 3"
Floor of 1" Boarding or Trenchboarding.
2"x 2" Fillet.
"B"
6' 0"

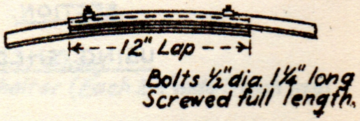
SECTION


3" Overlap
2'6"
2'6"
2'6"
2'6"
2'9"

PERSPECTIVE.


2"x 2" Fillet.
3"
4"x 3" Bearers.

DETAIL AT "B"


12" Lap
Bolts ½" dia. 1¼" long Screwed full length.

DETAIL AT "A".

SPLINTER-PROOF SHELTER.

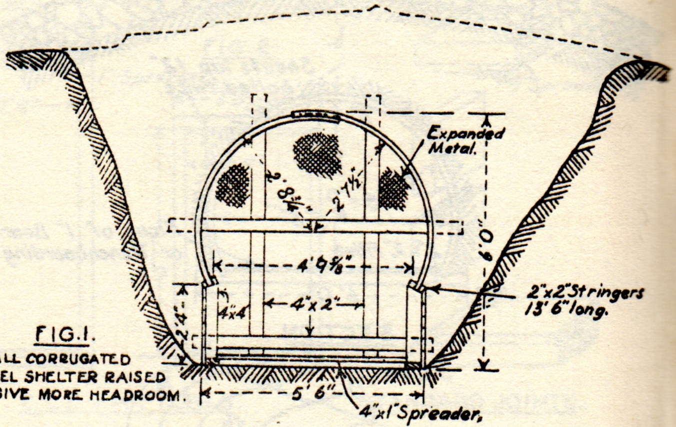
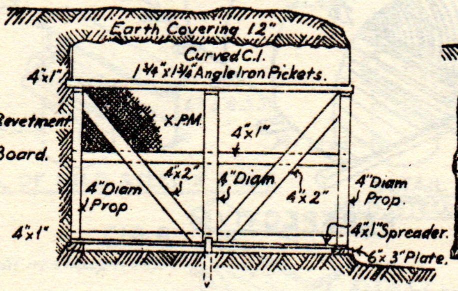

Expanded Metal.
2' 8¼"
2' 7½"
6' 0"
4' 9⅝"
4"x4"
4"x 2"
2' 4"
2"x2" Stringers 13' 6" long.
5' 6"
4"x1" Spreader.

FIG. 1.
SMALL CORRUGATED STEEL SHELTER RAISED TO GIVE MORE HEADROOM.


Earth Covering 12"
Curved C.I.
1¾"x1¾" Angle Iron Pickets.
4"x1"
X.P.M. Revetment
X.P.M.
4"x1"
4"x1" Board.
4"x2"
4" Diam
4"x2"
4" Diam Prop
4" Diam Prop.
4"x1"
4"x1" Spreader.
6"x3" Plate.

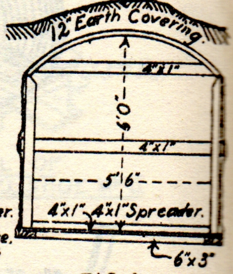
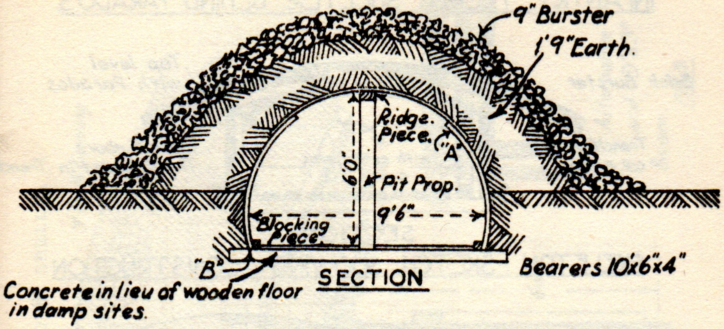

12" Earth Covering.
4"x1"
6' 0"
4"x1"
5' 6"
4"x1"
4"x1" Spreader.
6"x3"

FIG. 2.
SECTION.

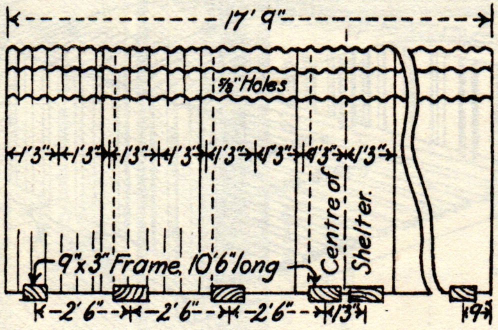
FIG. 3.
FRONT ELEVATION

USING SHEETS OF CURVED C.I.

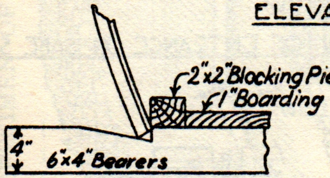
LARGE CORRUGATED STEEL SHELTER.

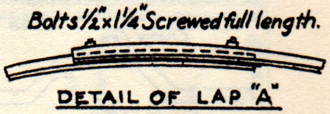

9" Burster
1' 9" Earth.
Ridge Piece.
"A"
6' 0"
Pit Prop.
9' 6"
Blocking Piece
"B"
Bearers 10'x6"x4"
Concrete in lieu of wooden floor in damp sites.

SECTION


17' 9"
⅝" Holes
1' 3"
1' 3"
1' 3"
1' 3"
1' 3"
1' 3"
1' 3"
1' 3"
Centre of Shelter.
9"x3" Frame 10' 6" long
2' 6"
2' 6"
2' 6"
1' 3"
9"

ELEVATION


2"x2" Blocking Piece.
1" Boarding
4"
6"x4" Bearers


Bolts ½"x1¼" Screwed full length.

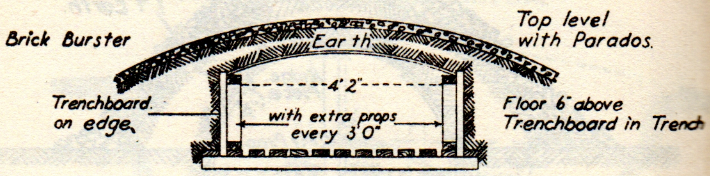
DETAIL OF "B"

DETAIL OF LAP "A"

Material required for each Shelter 17' 9" long
21 Sheets of large corrugated Shelter (Each 2' 9" wide 3 inch lap)
60 Bolts.
8 Bearers 10'x6"x4" 4 Pit Props.
160 Sq. Ft. of Boarding for floor
Gas-proof double door frame complete.
Accommodation double bunked 12 men in each shelter.

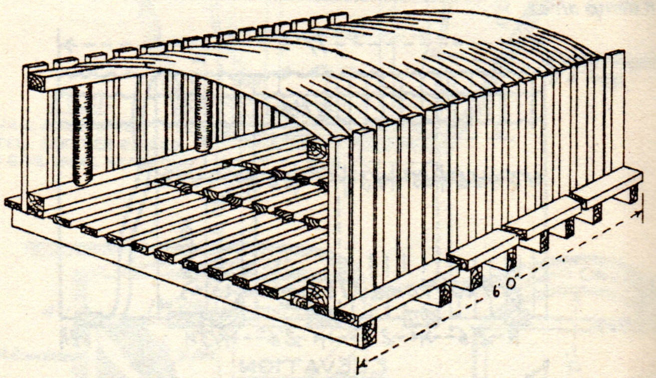
SHRAPNEL-PROOF SHELTERS.

INFANTRY TRENCH SHELTER BEHIND PARADOS.

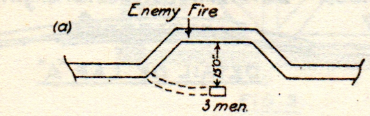

Brick Burster
Earth
Top level with Parados.
4'2"
Trenchboard. on edge
with extra props every 3'0"
Floor 6" above Trenchboard in Trench

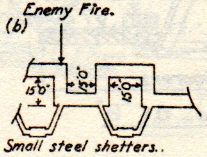
SECTION

SKELETON SKETCH SHOWING CONSTRUCTION



SKETCH SHOWING POSITION OF ENTRANCE ON SAFE SIDE


(a)
Enemy Fire
15'0"
3 men.

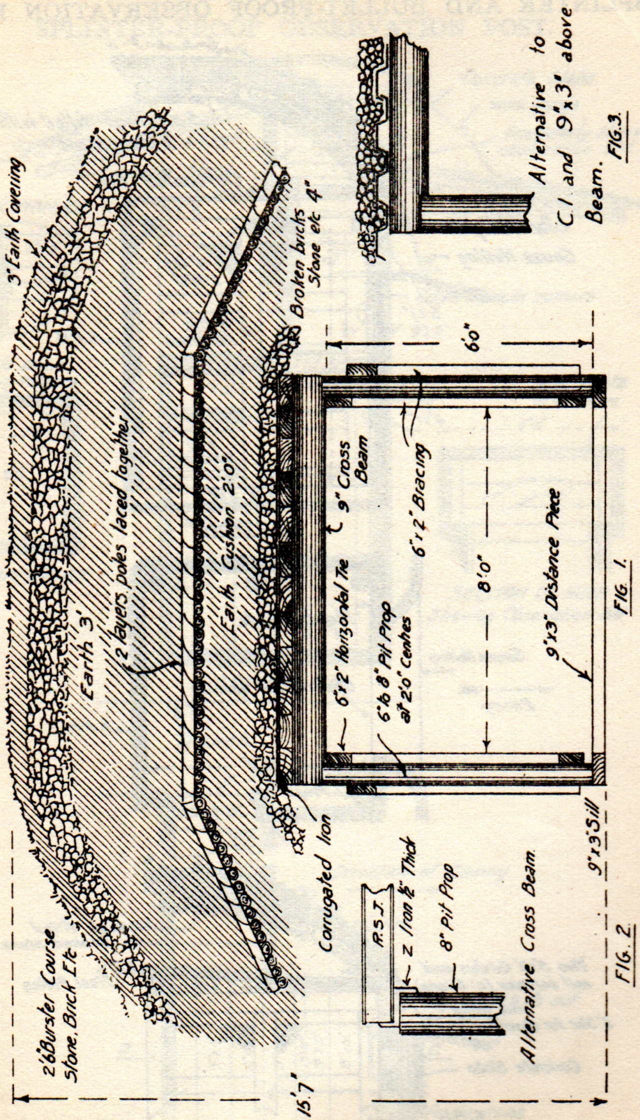

(b)
Enemy Fire.
15'0"
5'0"
15'0"
Small steel shelters..

MATERIAL REQUIRED.

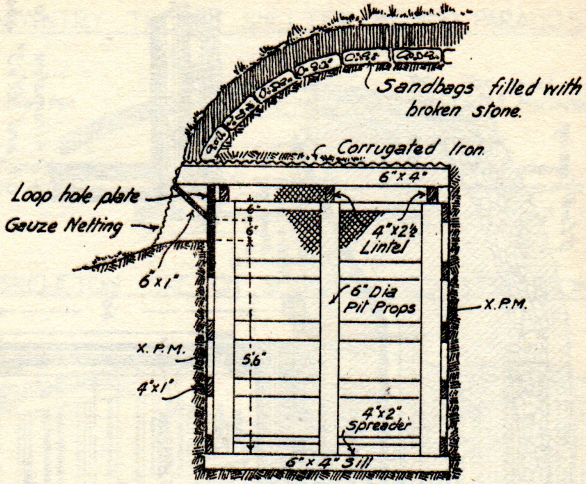
3. Curved sheets of small corrugated steel shelter.
2. Trenchboards for sides..
4. Trenchboards for floor.
2. Old corrugated sheets or boarding to form back.
Brick rubble for top cover.
Accommodation — 2 to 3 men.

NOTE:—Level of bottom of fire trench will regulate bottom of shelter, i.e. there will be a gradual grade from bottom of shelter to bottom of fire trench for drainage.

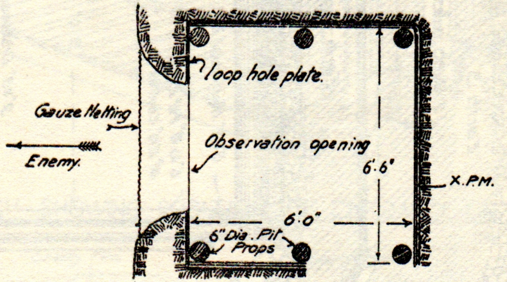
SPECIMEN OF SUITABLE COVER (UP TO 6" SHELLS).


Alternative to C.I. and 9"x3" above Beam.
FIG. 3.
3" Earth Covering
2'6" Burster Course Stone, Brick Etc
Earth 3'
2 layers poles laced together
Earth Cushion 2'0"
Broken bricks Stone etc 4"
6'0"
9" Cross Beam
6"x2" Bracing
6"x2" Horizontal Tie
6" to 8" Pit Prop at 2'0" Centres
8'0"
9"x3" Distance Piece
FIG. 1.
Corrugated Iron
9"x3" Sill
15'7"
R.S.J.
Z Iron ½" Thick
8" Pit Prop
Alternative Cross Beam
FIG. 2.

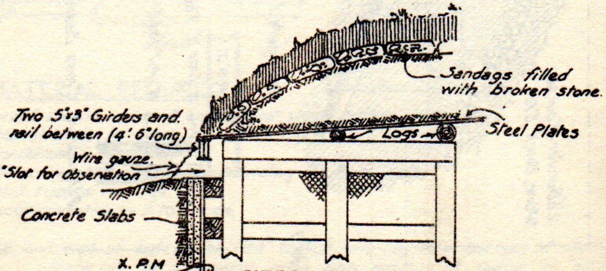
SPLINTER AND BULLET-PROOF OBSERVATION POST.


Sandbags filled with broken stone.
Corrugated Iron
6"x4"
Loop hole plate
Gauze Netting
6"x1"
6"
6"
4"x2½" Lintel
6" Dia Pit Props
X.P.M.
X.P.M.
5'6"
4"x1"
4"x2" Spreader
6"x4" Sill

SECTION.

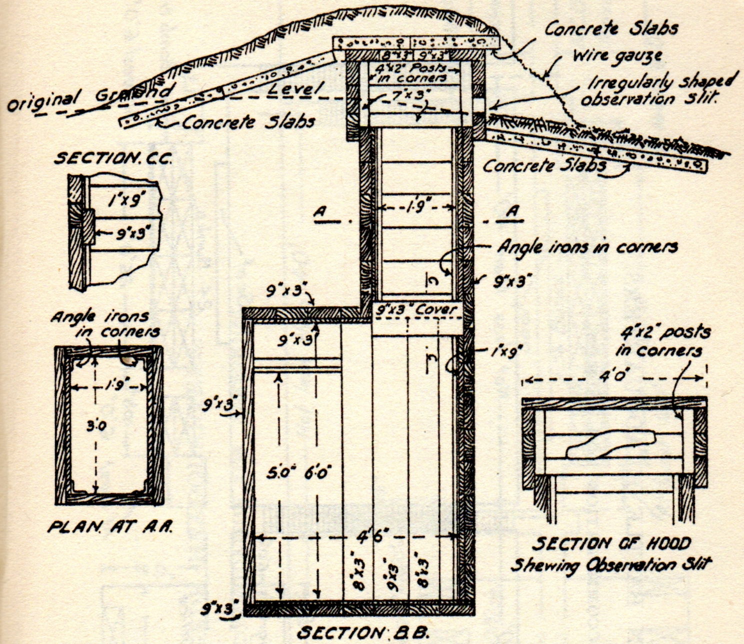

loop hole plate.
Gauze Netting
Enemy.
Observation opening
6'6"
X.P.M.
6'0"
6" Dia. Pit Props

PLAN

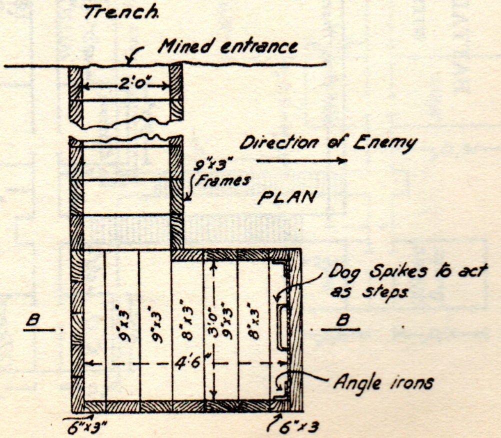

Sandags filled with broken stone.
Two 5"x3" Girders and rail between (4'6" long)
Logs
Steel Plates
Wire gauze.
6" Slot for Observation
Concrete Slabs
X.P.M

ALTERNATIVE HEAD PIECE.

SPLINTER-PROOF OBSERVATION POST.


Concrete Slabs
Wire gauze
Irregularly shaped observation slit.
Original Ground Level
Concrete Slabs
Concrete Slabs
8"x3"
9"x3"
4"x2" Posts in corners
7"x3"
SECTION. CC.
1"x9"
9"x3"
A
A
1'9"
Angle irons in corners
9"x3"
9"x3"
9"x3" Cover
Angle irons in corners
9"x3"
1"x9"
1'9"
3'0"
PLAN. AT A.A.
9"x3"
5'0"
6'0"
4'6"
8"x3"
9"x3"
8"x3"
9"x3"
4"x2" posts in corners
4'0"
SECTION OF HOOD Shewing Observation Slit

SECTION. B.B.

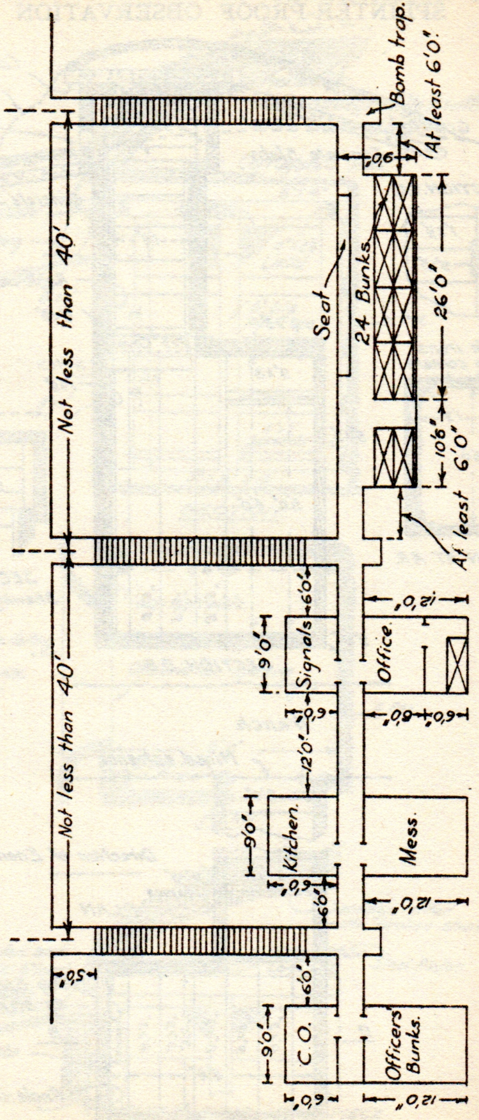

Trench.
Mined entrance
2'0"
Direction of Enemy
9"x3" Frames
Dog Spikes to act as steps.
B
B
9"x3"
9"x3"
8"x3"
3'0"
9"x3"
8"x3"
4'6"
Angle irons
6"x3"
6"x3

PLAN

PLATE 44. [*Ref. Sec.* **21**, 1 *and* 9.

BATTALION BATTLE HEADQUARTERS.

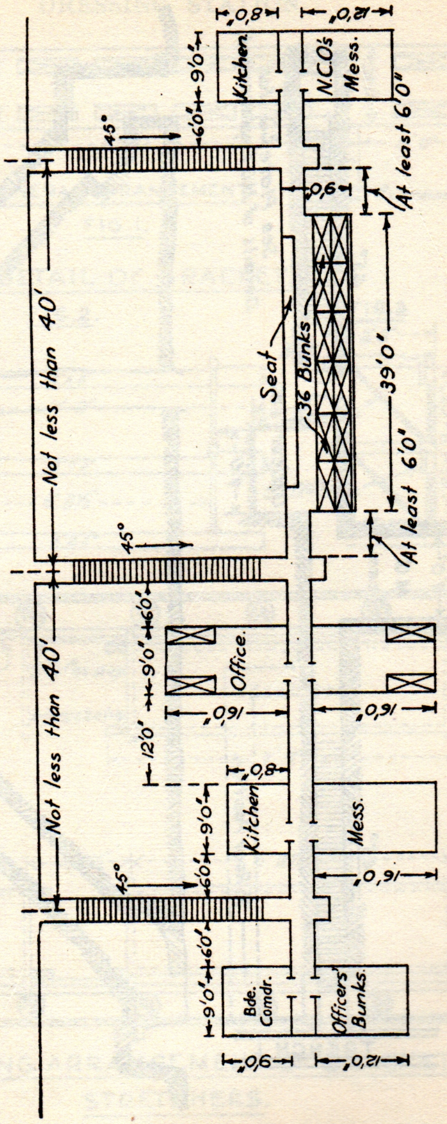
WITH ACCOMMODATION FOR 28 MEN.


Bomb trap.
At least 6'0"
6'0"
Not less than 40'
Seat
24 Bunks
26'0"
10'6"
At least 6'0"
Not less than 40'
Signals
6'0"
9'0"
6'0"
12'0"
Office.
12'0"
6'0"
6'0"
Not less than 40'
Kitchen.
9'0"
6'0"
6'0"
Mess.
12'0"
5'0"
6'0"
C.O.
9'0"
6'0"
Officers' Bunks.
12'0"

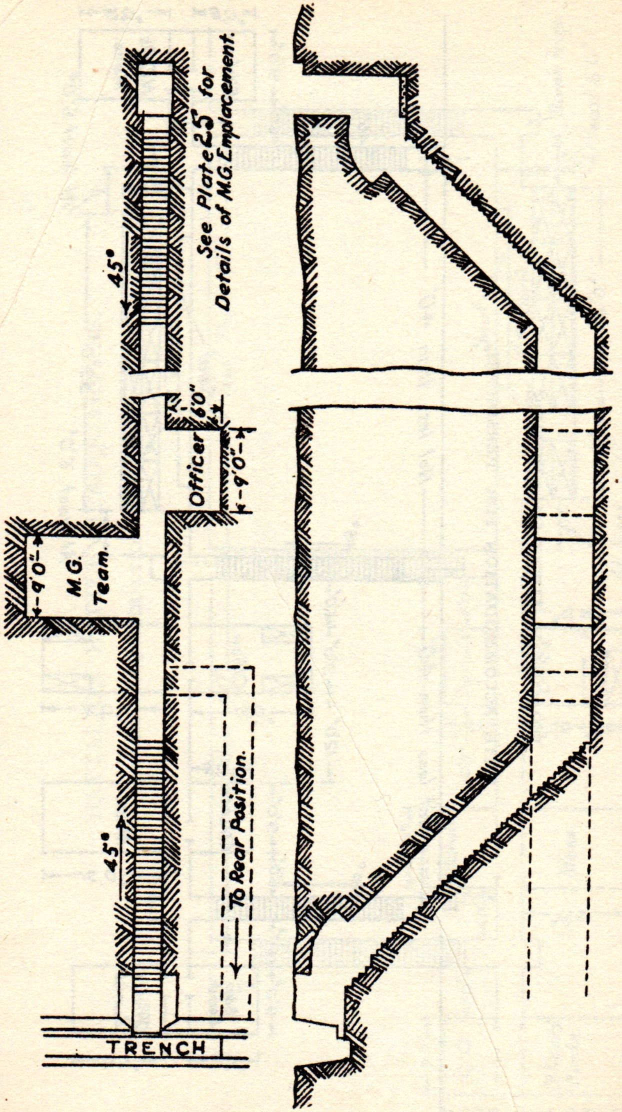
Ref. Sec. **21**, 1.] **PLATE 45.**

BRIGADE HEADQUARTERS.

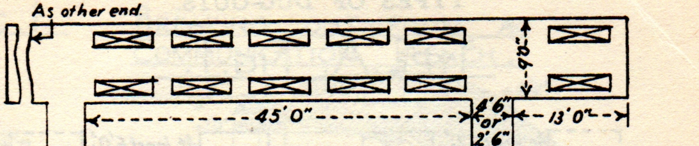
WITH ACCOMMODATION FOR PERSONNEL.


8'0"
12'0"
Kitchen.
N.C.O's Mess.
9'0"
6'0"
At least 6'0"
45°
6'0"
Not less than 40'
Seat
36 Bunks
39'0"
At least 6'0"
45°
6'0"
Office.
9'0"
6'0"
19'0"
19'0"
12'0"
8'0"
Not less than 40'
Kitchen
9'0"
Mess.
45°
6'0"
19'0"
6'0"
Bde. Comdr.
9'0"
Officers' Bunks.
6'0"
12'0"

M.G. DUG-OUT AND EMPLACEMENT


45°
See Plate 25 for Details of M.G. Emplacement.
6'0"
Officer
9'0"
9'0"
M.G. Team
45°
To Rear Position.
TRENCH

DRESSING STATION.


As other end.
9'0"
45'0"
4'6" or 2'6"
13'0"
Entrance slope ½.

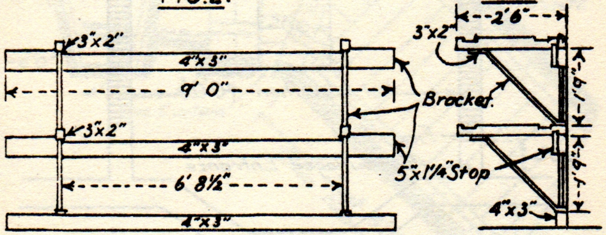
GENERAL ARRANGEMENT

FIG. 1.

DETAIL OF BRACKETS.

FIG. 2.

FIG. 3.


3"x2"
4"x3"
9'0"
3"x2"
4"x3"
6' 8½"
4"x3"
Bracket
5"x1¼" Stop
2'6"
3"x2"
1'9"
1'9"
4"x3"

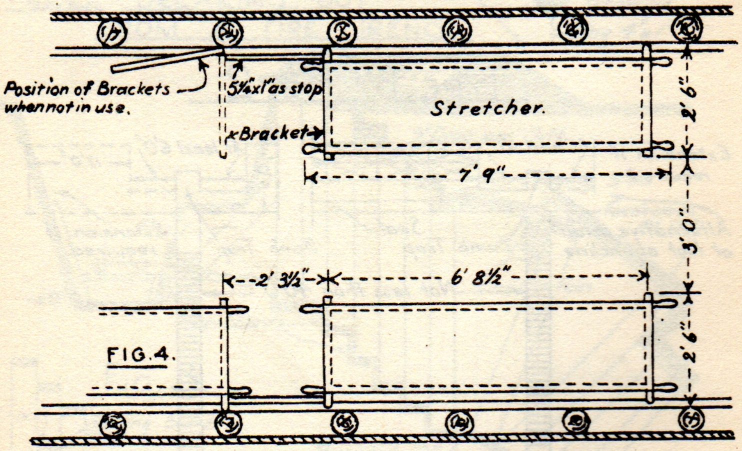
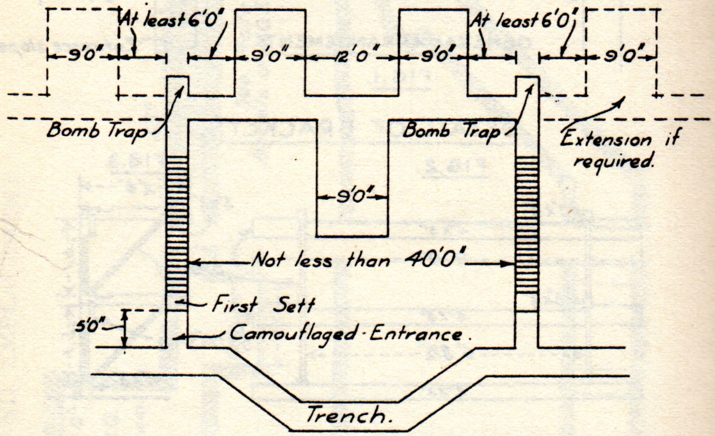

Position of Brackets when not in use.
5¼"x1" as stop
Bracket
Stretcher.
2'6"
7'9"
3'0"
2'3½"
6'8½"
2'6"

FIG. 4.

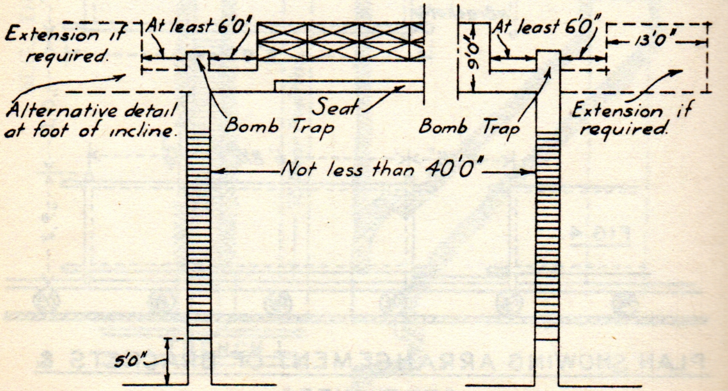
PLAN SHOWING ARRANGEMENT OF BRACKETS & STRETCHERS.

TYPES OF DUG-OUTS.

TYPE. A. FIG. 1.


At least 6'0"
9'0"
9'0"
12'0"
9'0"
At least 6'0"
9'0"
Bomb Trap
Bomb Trap
Extension if required.
9'0"
Not less than 40'0"
First Sett
5'0"
Camouflaged Entrance.
Trench.

TYPE. B. FIG. 2.


Extension if required.
At least 6'0"
9'0"
At least 6'0"
13'0"
Alternative detail at foot of incline.
Seat
Bomb Trap
Bomb Trap
Extension if required.
Not less than 40'0"
5'0"

INCLINES

FIG. 1. BREAKING OUT FROM A COMMUNICATION TRENCH.

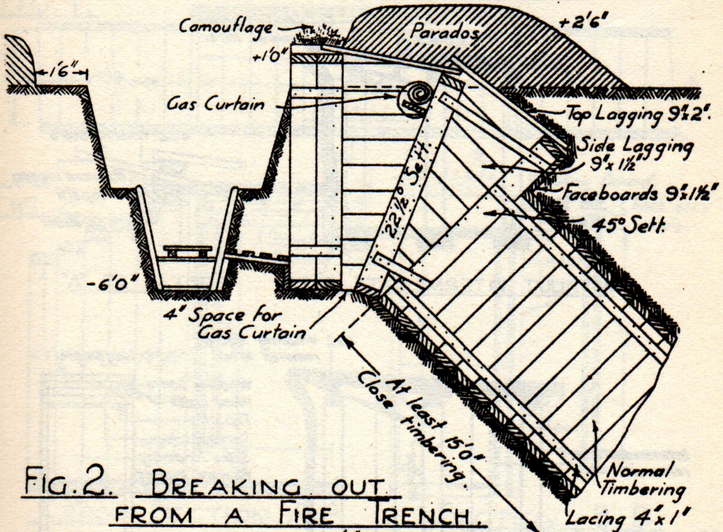

Camouflage
Parados
+2'6"
+1'0"
1'6"
Gas Curtain
Top Lagging 9"x2".
Side Lagging 9"x1½"
Faceboards 9"x1½"
22½° Sett.
45° Sett.
-6'0"
4" Space for Gas Curtain
At least 15'0" Close timbering.
Normal Timbering
Lacing 4"x1"

FIG. 2. BREAKING OUT FROM A FIRE TRENCH.

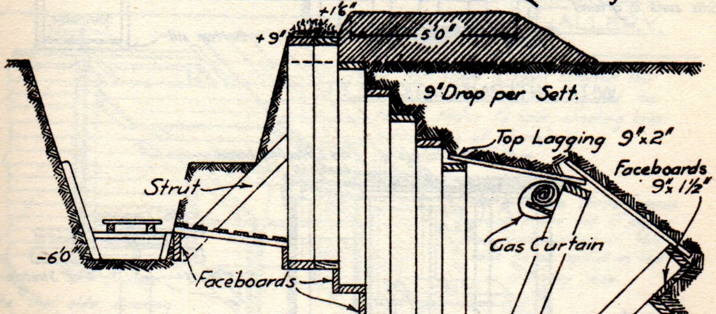
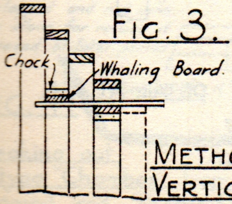
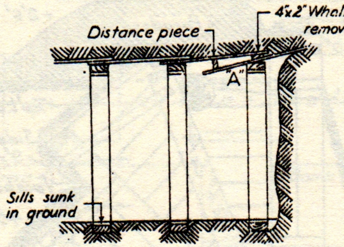

+1'6"
+9"
5'0"
9" Drop per Sett.
Top Lagging 9"x2"
Faceboards 9"x1½"
Strut
Gas Curtain
-6'0"
Faceboards
4" Space for Gas Curtain

FIG. 3.

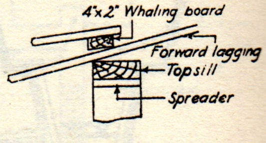

Chock
Whaling Board

METHOD OF SPILING WITH VERTICAL TIMBERING IN BAD GROUND.

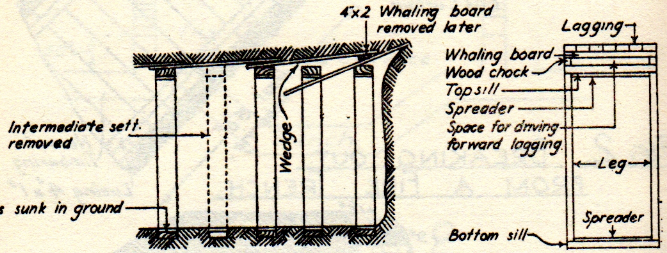
SPILING.


Distance piece
4"x2" Whaling board removed later
"A"
Sills sunk in ground

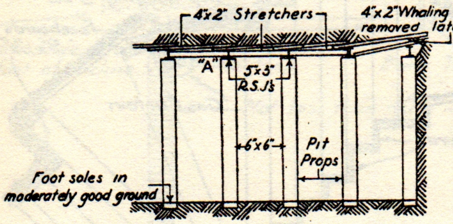
WITHOUT INTERMEDIATE SETT.


4"x2" Whaling board
Forward lagging
Topsill
Spreader

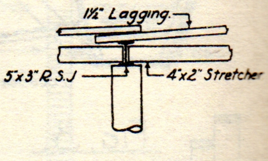
DETAIL AT "A"


4"x2 Whaling board removed later
Wedge
Intermediate sett. removed
Sills sunk in ground
Lagging
Whaling board
Wood chock
Topsill
Spreader
Space for driving forward lagging
Leg
Spreader
Bottom sill

WITH INTERMEDIATE SETT


4"x2" Stretchers
4"x2" Whaling board removed later
"A"
5"x5" R.S.J's
6"x6"
Pit Props
Foot soles in moderately good ground

WITH PIT PROPS AND R SJ's.


1½" Lagging
5"x3" R.S.J
4"x2" Stretcher

DETAIL AT 'A'.

BREAKING OUT "A" TYPE CHAMBER FROM NORMAL GALLERY.

FIG. 1.

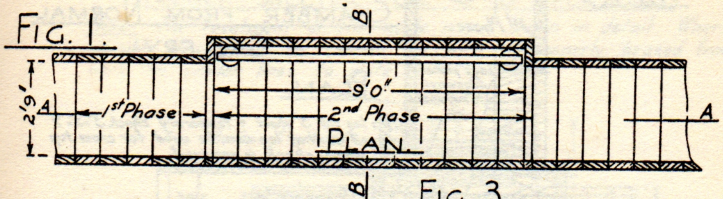
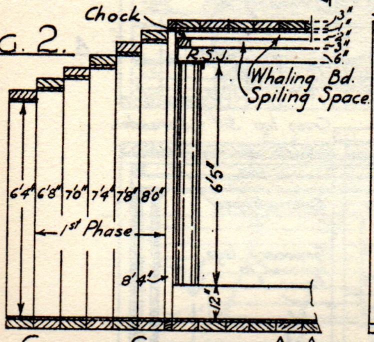
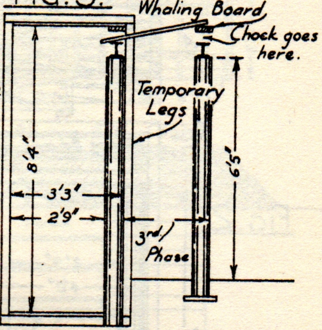

B
B
A
A
2'9"
1st Phase
9'0"
2nd Phase
PLAN.

FIG. 2.


Chock
3"
3"
3"
6"
R.S.J.
Whaling Bd. Spiling Space.
6'4"
6'8"
7'0"
7'4"
7'8"
8'0"
6'5"
1st Phase
8'4"
1'2"

CROSS SECTION A-A.

FIG. 3.


Whaling Board
Chock goes here.
Temporary Legs
8'4"
3'3"
2'9"
6'5"
3rd Phase

SECTION B-B THRO' GALLERY.

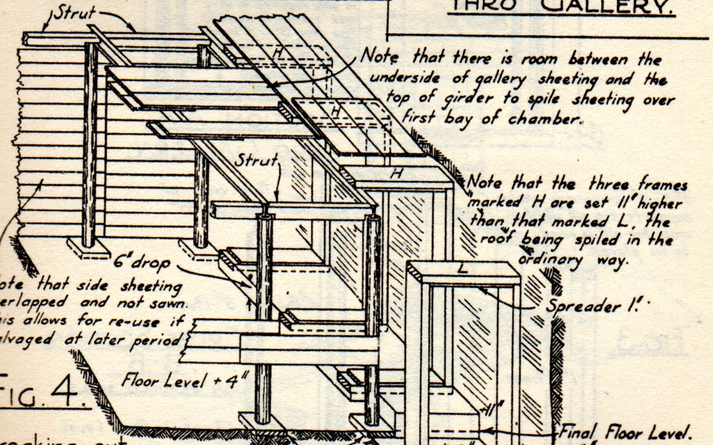

Strut
H
H
H
Strut
L
Note that there is room between the underside of gallery sheeting and the top of girder to spile sheeting over first bay of chamber.
Note that the three frames marked H are set 11" higher than that marked L, the roof being spiled in the ordinary way.
6" drop
Note that side sheeting overlapped and not sawn. This allows for re-use if salvaged at later period.
Spreader 1'.
Floor Level + 4"
11"
±0"
Final Floor Level. + 4"
Foot soles

FIG. 4.

Breaking out 'A' type Chamber from Framed and Sheeted Gallery.

FIG. 1.

BREAKING OUT 'B' TYPE CHAMBER FROM NORMAL GALLERY.

PLAN.

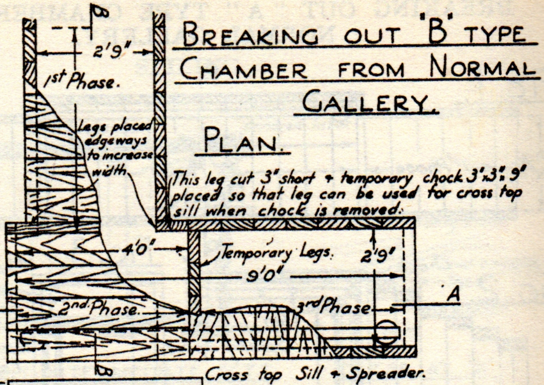
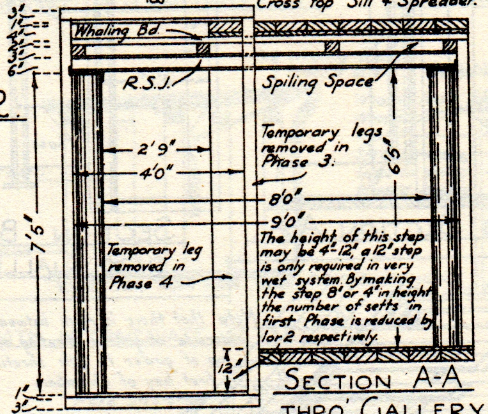
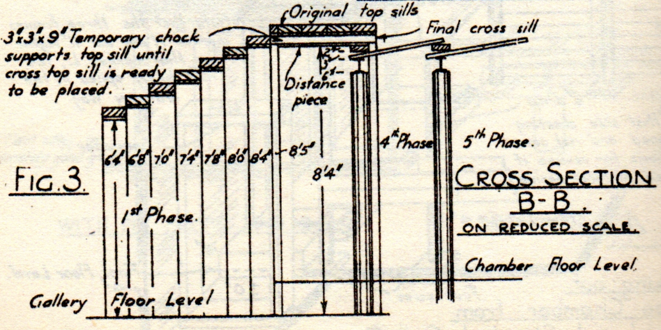

B
2'9"
1st Phase.
Legs placed edgeways to increase width.
This leg cut 3" short + temporary chock 3"x3"x9" placed so that leg can be used for cross top sill when chock is removed.
4'0"
Temporary Legs.
2'9"
9'0"
A
2nd Phase.
3rd Phase
A
B
Cross top Sill + Spreader.

FIG. 2.


3"
1½"
4"
2"
3"
6"
Whaling Bd
R.S.J.
Spiling Space
2'9"
4'0"
Temporary legs removed in Phase 3.
6'5"
8'0"
9'0"
7'5"
Temporary leg removed in Phase 4
The height of this step may be 4"-12", a 12" step is only required in very wet system. By making the step 8" or 4" in height the number of setts in first Phase is reduced by 1 or 2 respectively.
12"
1"
3"

SECTION A-A THRO' GALLERY.

FIG. 3.

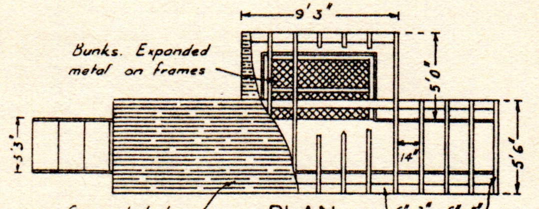

Original top sills
3"x3"x9" Temporary chock supports top sill until cross top sill is ready to be placed.
Final cross sill
Distance piece
6"
6'4"
6'8"
7'0"
7'4"
7'8"
8'0"
8'4"
8'5"
8'4"
4th Phase
5th Phase
1st Phase.
Chamber Floor Level.
Gallery Floor Level

CROSS SECTION B-B.
ON REDUCED SCALE.

PROTECTION FROM AIR RAIDS.

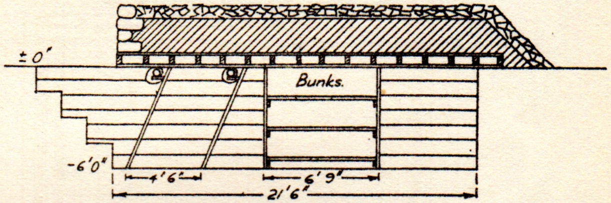
TRENCH SHELTER FOR 6-8 PERSONS.

Note: The revetment of the inside is not shewn in detail. Where possible this should be carried out with a properly braced framework on similar lines to plate 36. M.F.E. Vol. I.

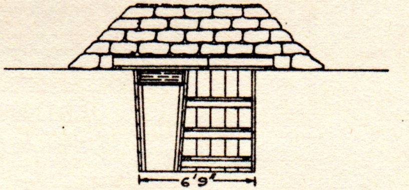

9'3"
Bunks. Expanded metal on frames
5'0"
3'3"
14"
5'6"
Corrugated Iron
6"x2"
6"x5"

PLAN.

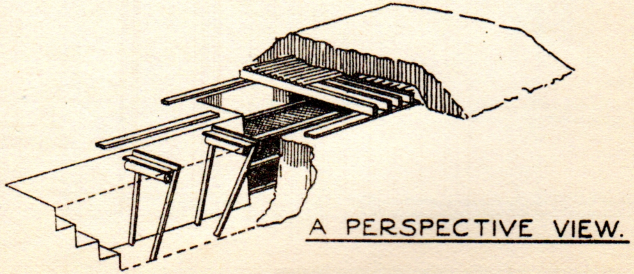
Brick rubble 9" over 2'0" of earth.


±0'
Bunks.
-6'0"
4'6"
6'9"
21'6"

SECTION.



SECTION AT BUNKS.



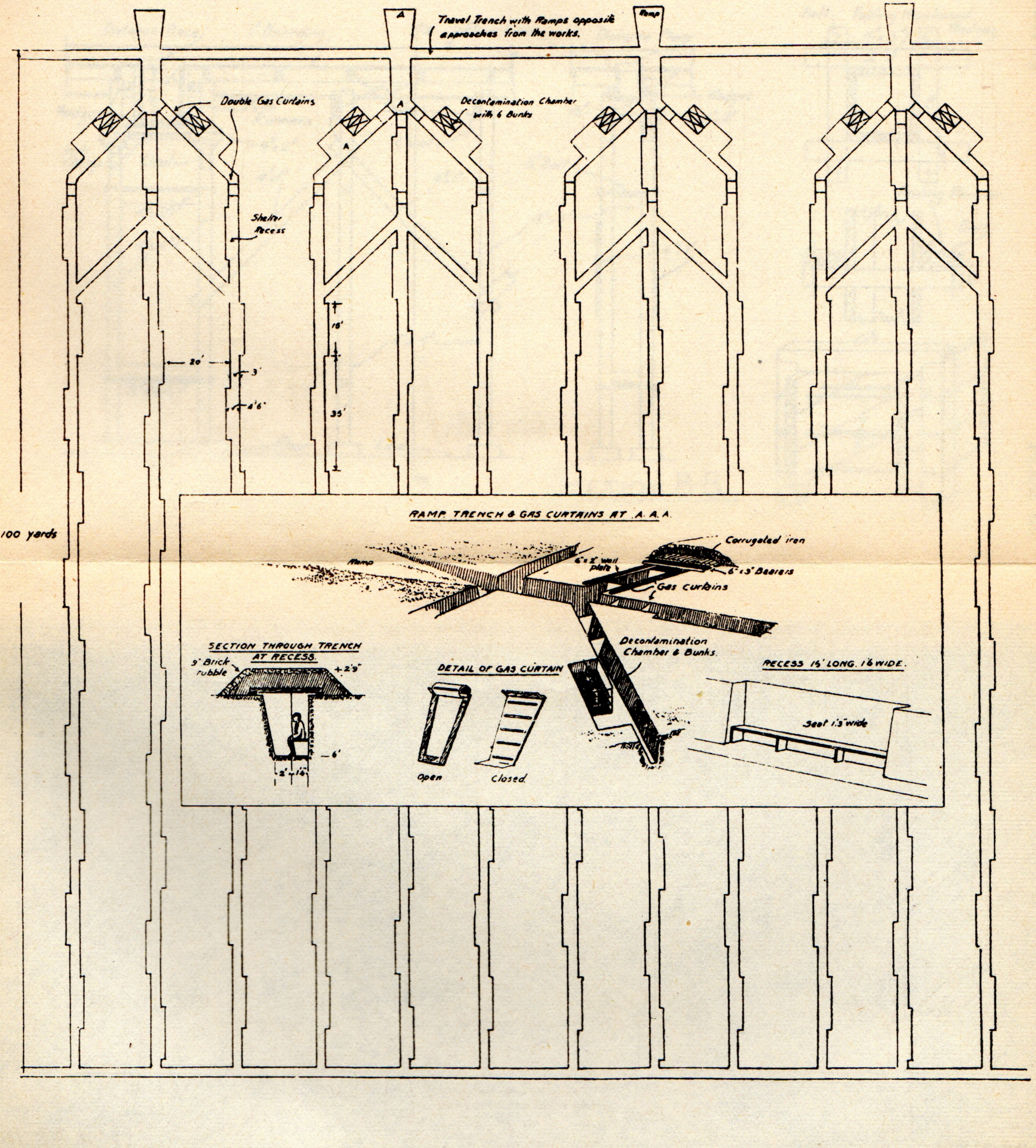
A PERSPECTIVE VIEW.

TRENCH SHELTER SYSTEM.

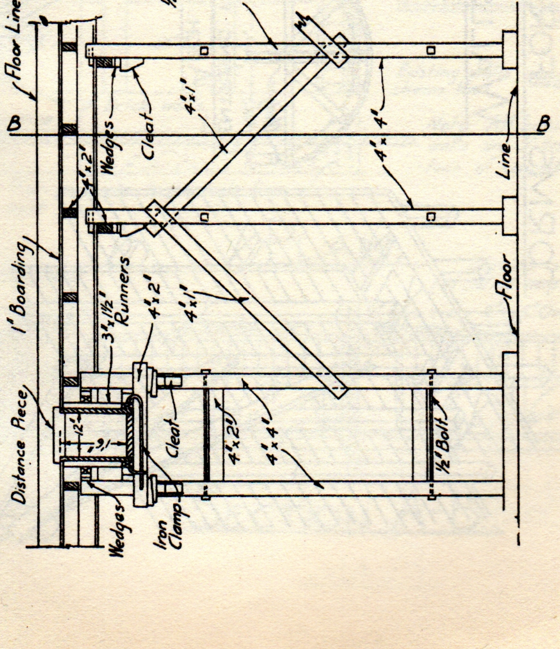
Accommodating 1,200 to 1,500 persons in area 100 yards by 100 yards.

Ref. Sec. **26**, 4.]

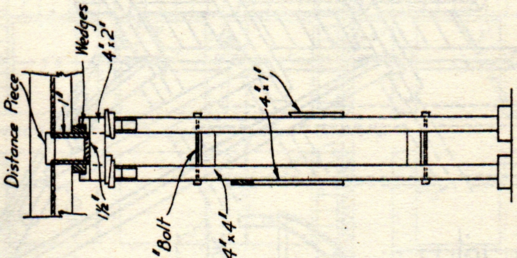
PLATE 54.


Travel Trench with Ramps opposite approaches from the works.
A
Ramp
Double Gas Curtains
Decontamination Chamber with 6 Bunks
A
A
Shelter Recess
20'
3'
4'6"
15'
35'
100 yards
RAMP. TRENCH & GAS CURTAINS AT A. A. A.
Corrugated iron
Ramp
6" x 2" wall plate
6" x 3" Bearers
Gas curtains
Decontamination Chamber & Bunks.
SECTION THROUGH TRENCH AT RECESS.
9" Brick rubble
+2'9"
6'
2'
1'6"
DETAIL OF GAS CURTAIN
Open
Closed.
RECESS 15' LONG. 1'6 WIDE.
Seat 1'3" wide

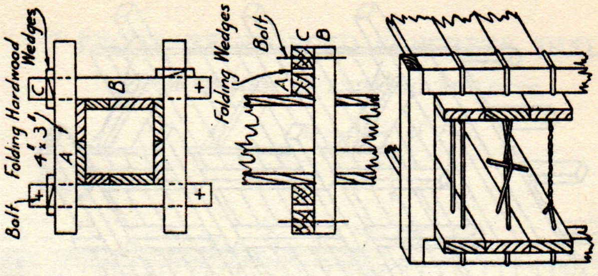
MAIN BEAM MOULD.

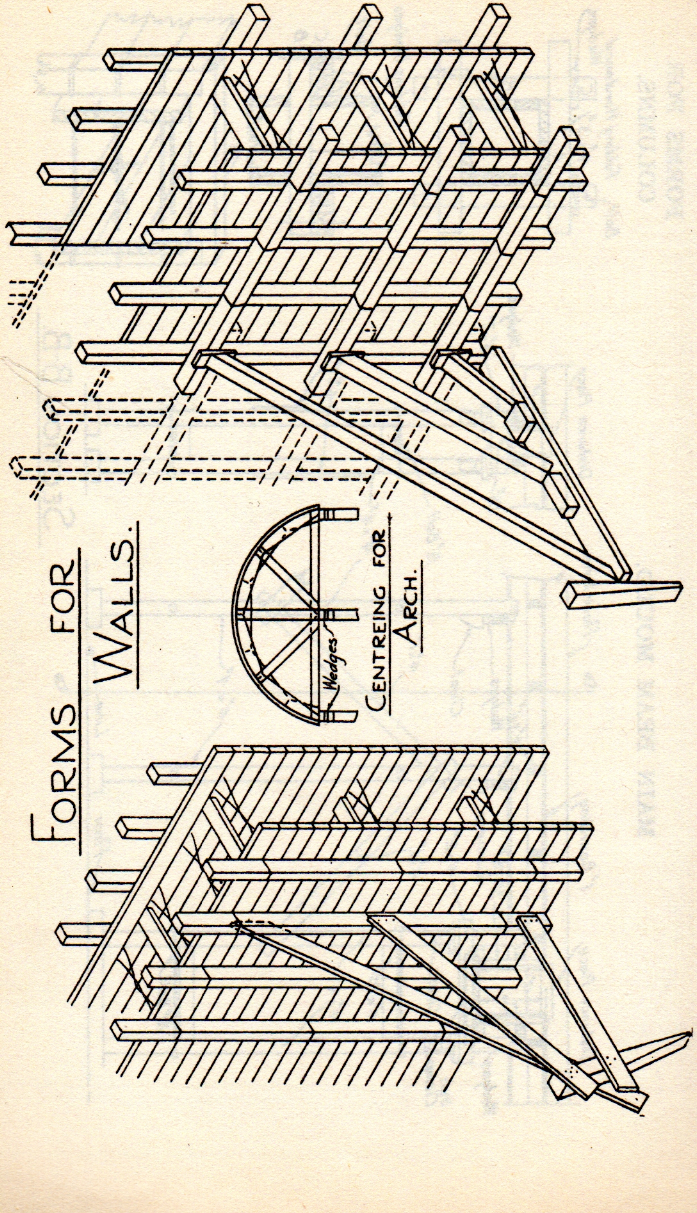

Floor Line
B
B
1" Boarding
Distance Piece
Wedges
Iron Clamp
12"
6"
Cleat
4"x2"
4"x4"
3"x1½" Runners
4"x2"
Wedges
Cleat
4"x1"
4"x1"
4"x1"
4"x4"
4"x4"
½" Bolt
Line
Floor

SECTION B-B.


Distance Piece
Wedges
4"x2"
1½"
1½"
½" Bolt
4"x4"
4"x1"

FORMS FOR COLUMNS.


Bolt
Folding Hardwood Wedges
4"x3"
A
B
C
Folding Wedges
Bolt
A
C
B

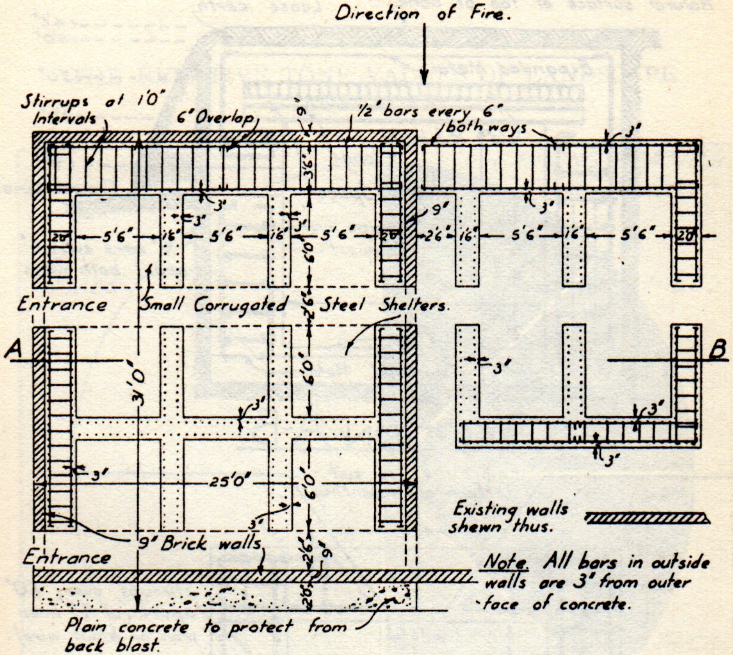


FORMS FOR WALLS.

CENTREING FOR ARCH.

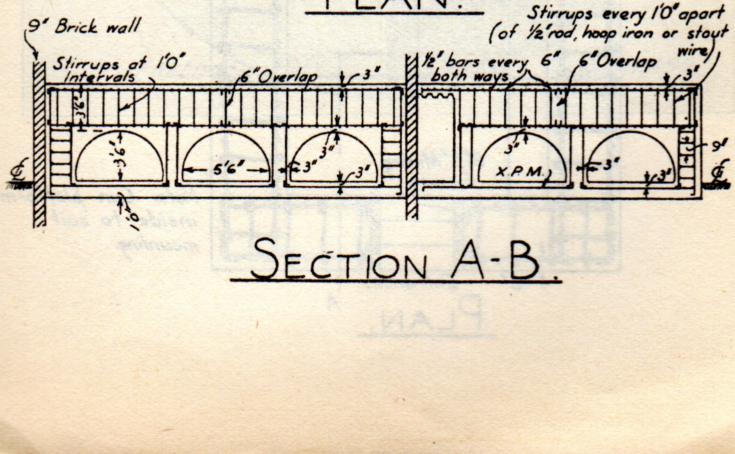
5·9" PROOF REINFORCED CONCRETE SHELTER.

FOR 40 MEN IN EXISTING BUILDING.



Direction of Fire.
Stirrups at 1'0" Intervals
6" Overlap
9"
½" bars every 6" both ways
3"
3'6"
3"
2'0"
5'6"
1'6"
5'6"
1'6"
5'6"
2'0"
9"
2'6"
1'6"
5'6"
1'6"
5'6"
2'0"
6'0"
Entrance
Small Corrugated Steel Shelters.
2'6"
A
B
3'
3'
3'
31'0"
6'0"
6'0"
3"
25'0"
3'
3"
Existing walls shewn thus.
Entrance
9" Brick walls
2'6"
9"
2'6"
Note. All bars in outside walls are 3" from outer face of concrete.
Plain concrete to protect from back blast.

PLAN.

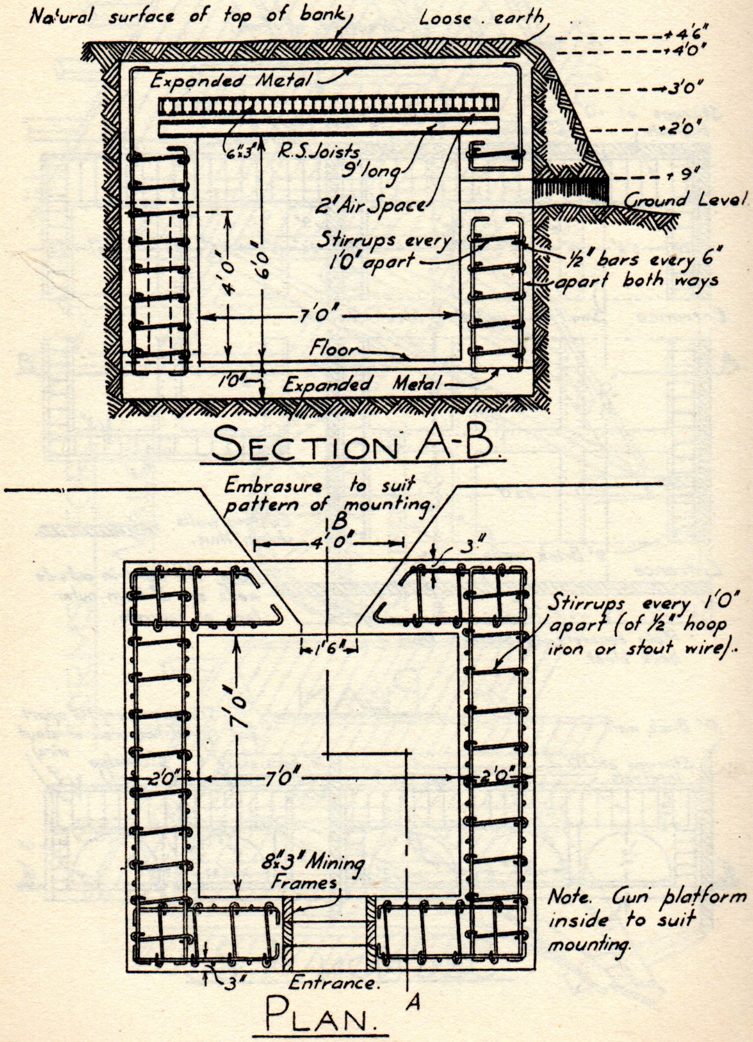


9" Brick wall
Stirrups every 1'0" apart (of ½" rod, hoop iron or stout wire)
Stirrups at 1'0" Intervals
6" Overlap
3"
½" bars every 6" both ways
6" Overlap
3"
3'6"
3'6"
5'6"
3"
3"
3"
3"
X.P.M.
3"
3"
9"
1'6"

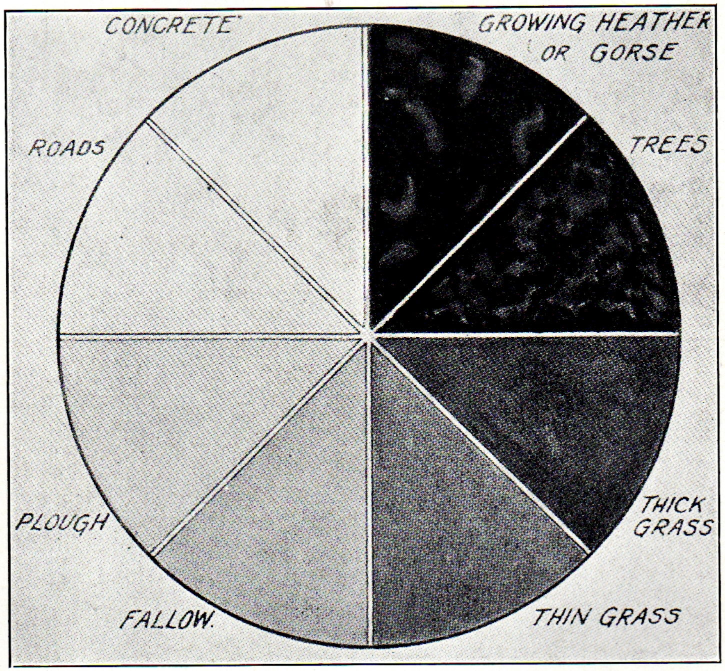
SECTION A-B.

MACHINE-GUN EMPLACEMENT.

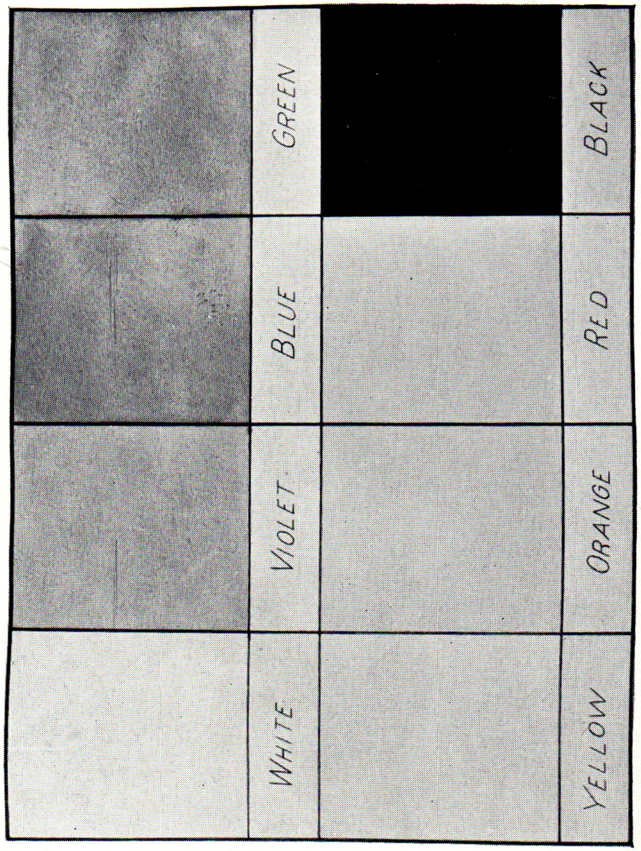
FOR ENFILADE FIRE WHERE CONCEALMENT IS NECESSARY, MEDIUM PROTECTION ONLY BEING POSSIBLE.


Natural surface of top of bank
Loose earth
+4'6"
+4'0"
+3'0"
+2'0"
+9"
Ground Level
Expanded Metal
6"×3"
R.S. Joists 9' long
2' Air Space
Stirrups every 1'0" apart
½" bars every 6" apart both ways
4'0"
6'0"
7'0"
Floor
1'0"
Expanded Metal
SECTION A-B.
Embrasure to suit pattern of mounting.
B
4'0"
3"
1'6"
Stirrups every 1'0" apart (of ½" hoop iron or stout wire).
7'0"
2'0"
7'0"
2'0"
8"×3" Mining Frames.
Note. Gun platform inside to suit mounting.
3"
Entrance.
A
PLAN.

THE RELATIVE TONE VALUES OF LANDSCAPE SURFACES.

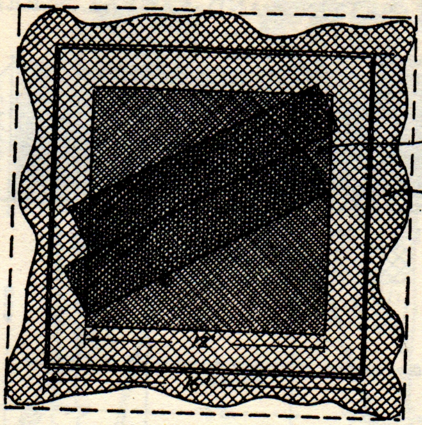


TONE VALUES OF COLOURS.

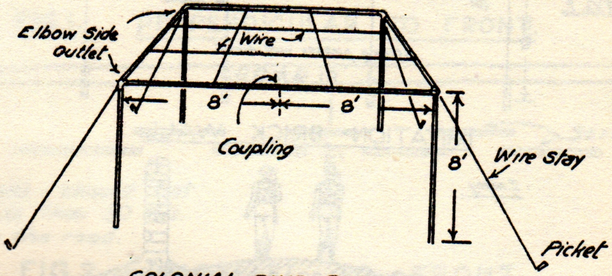


WIRE NETTING COVER.

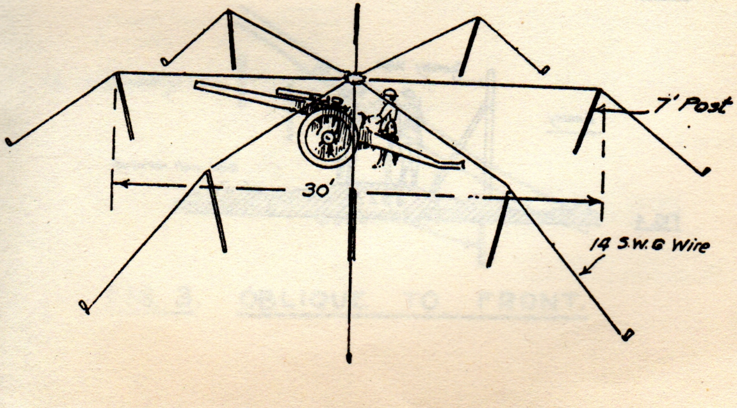
PLAN.


3/8" Mesh
1/2" Mesh
Painted Light green

PERSPECTIVE VIEW OF FRAME SUPPORT

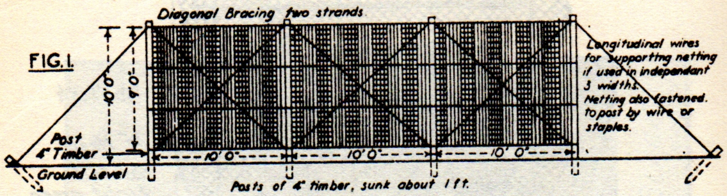

Elbow Side outlet
Wire
8'
8'
Coupling
8'
Wire Stay
Picket

COLONIAL RING SUPPORT.


7' Post
30'
14 S.W.G Wire

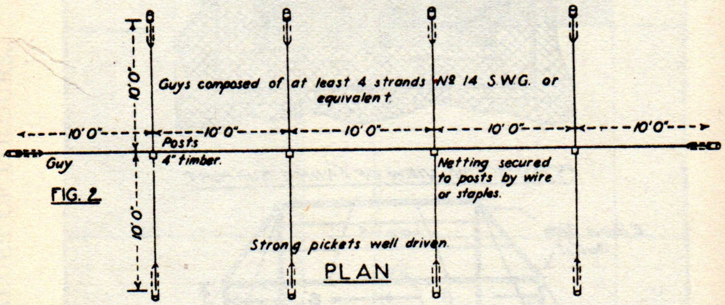
WIRE NETTING AND CANVAS SCREEN.

FIG. 1.


Diagonal Bracing two strands
10' 0"
9' 0"
Longitudinal wires for supporting netting if used in independant 3 widths. Netting also fastened to post by wire or staples.
Post 4" Timber
Ground Level
10' 0"
10' 0"
10' 0"
Posts of 4" timber, sunk about 1 ft.

ELEVATION

FIG. 2.


10' 0"
Guys composed of at least 4 strands № 14 S.W.G. or equivalent.
10' 0"
10' 0"
10' 0"
10' 0"
10' 0"
Posts
4" timber.
Guy
Netting secured to posts by wire or staples.
10' 0"
Strong pickets well driven.

PLAN

IMITATION BRICK WALL.

FIG. 3.

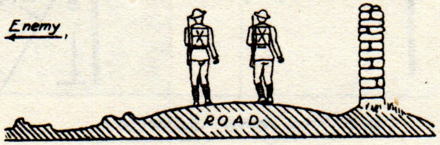
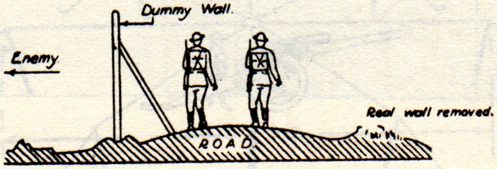


FIG. 4.


Dummy Wall.
Enemy
Real wall removed.
ROAD

SCREENING ROADS.

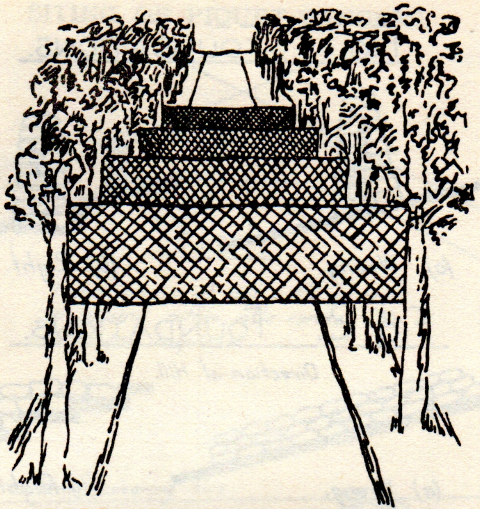
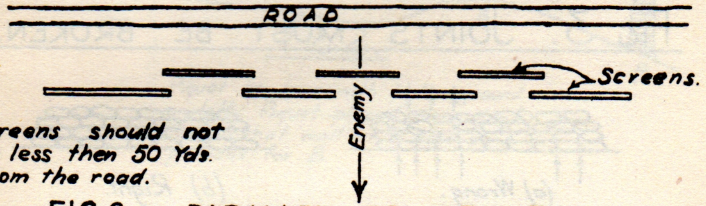


FIG. 1. PERPENDICULAR TO FRONT.


ROAD
Screens.
Enemy

Screens should not be less then 50 Yds. from the road.

FIG. 2. PARALLEL TO FRONT.

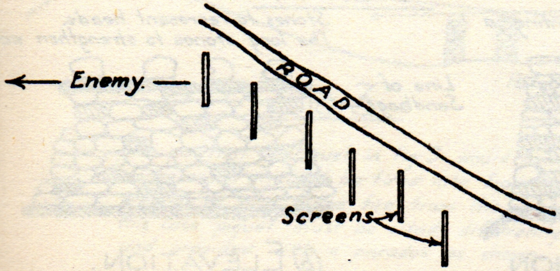
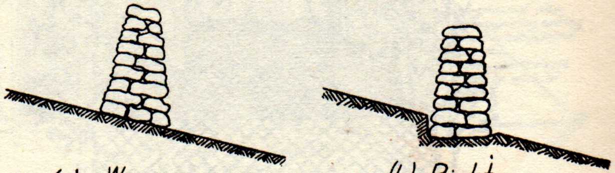

Enemy.
ROAD
Screens

FIG. 3. OBLIQUE TO FRONT.

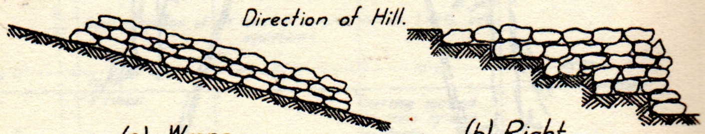
METHOD OF BUILDING SANGARS.

FIG. 1. FOUNDATIONS.



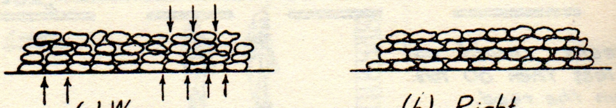
(a) Wrong. (b) Right.

FIG. 2. FOUNDATIONS.


Direction of Hill.

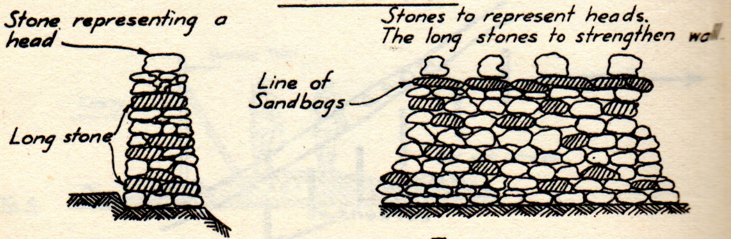
(a) Wrong. (b) Right.

FIG. 3. JOINTS MUST BE BROKEN.



(a) Wrong. (b) Right.

FIG. 4.


Stone representing a head
Stones to represent heads.
The long stones to strengthen wall
Line of Sandbogs
Long stone

(a) SECTION. (b) ELEVATION.

SITING OF PIQUET SANGARS.

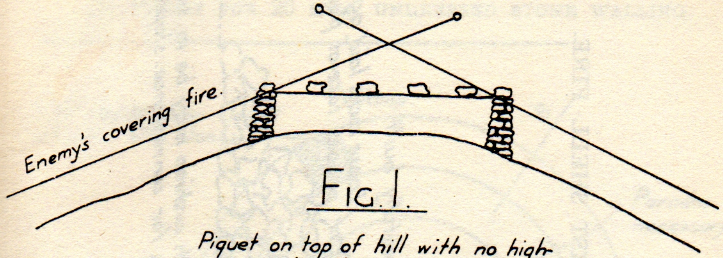

Enemy's covering fire.

FIG. 1.

Piquet on top of hill with no higher ground within rifle range. No parados required.

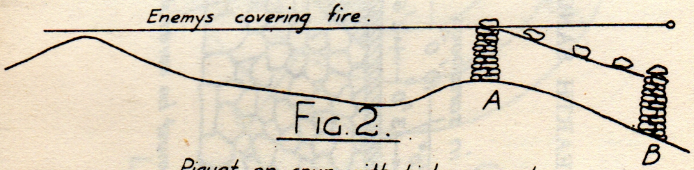

Enemys covering fire.
A
B

FIG. 2.

Piquet on spur with higher ground on left. Piquet placed down the hill so that wall at A acts as parados for B.

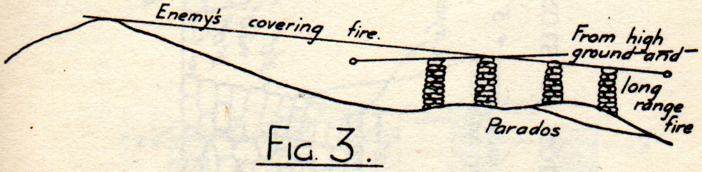
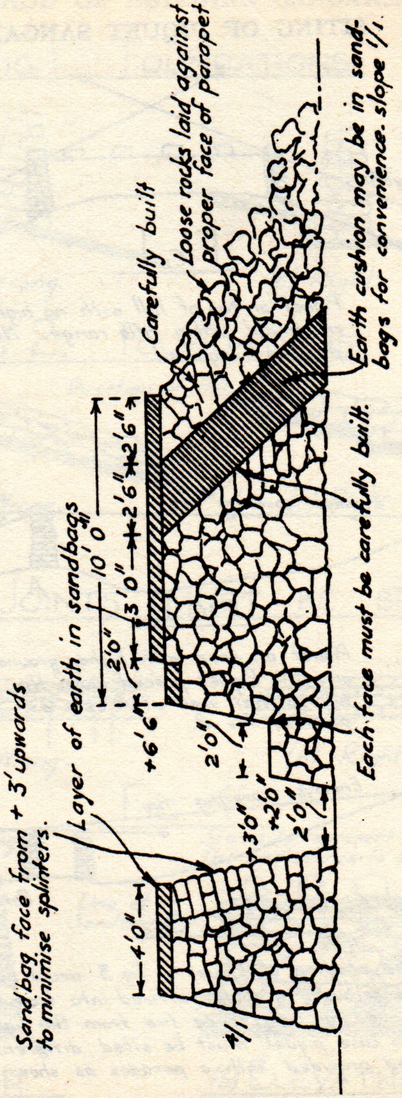

Enemy's covering fire.
From high ground and long range fire
Parados

FIG. 3.

The position of Piquet in fig: 3 would be very dangerous if it could be fired into from higher ground or long range fire from the right. In this case piquet must be sited differently. and provided with a parados as shewn.

SECTION OF STONE AND EARTH SANGAR TO RESIST SHELL FIRE.


Sandbag face from + 3' upwards to minimise splinters.
4'0"
Layer of earth in sandbags 4"
+3'0"
+2'0"
2'0"
2'0"
+6'6"
2'0"
3'0"
10'0"
2'6"
2'6"
2'6"
Carefully built
Loose rocks laid against proper face of parapet
Earth cushion may be in sandbags for convenience. slope 1/1
Each face must be carefully built.
4/1

TYPES OF SANGARS.

(*a*) PIQUET FOR 20 MEN, UNDRESSED STONE WALLING.

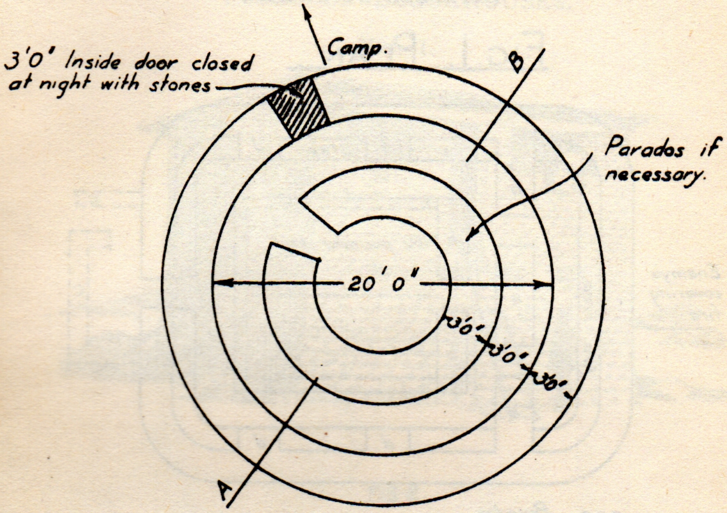

Camp.
3'0" Inside door closed at night with stones
B
Parados if necessary.
20'0"
3'0"
3'0"
3'0"
A

FIG. 1. IN LEVEL COUNTRY.

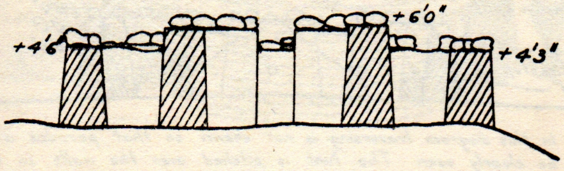
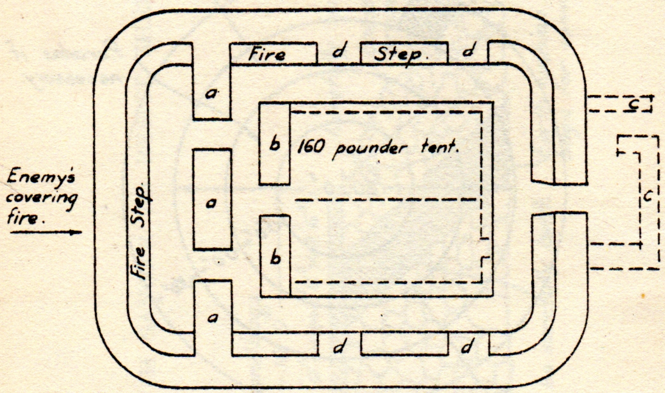


FIG. 2. SECTION ON A-B.

TYPES OF SANGARS.

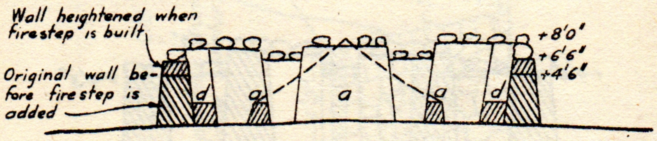
(*b*) PIQUET FOR 48 MEN, DRESSED STONE. THIS PIQUET CAN BE DEFENDED BY 24 MEN.

FIG. 1. PLAN.


Fire
d
Step.
d
a
b
160 pounder tent.
a
b
a
d
d
c
c
Enemy's covering fire.
Fire Step.

aaa	Parados.
bb	Traverses in the parados to give cover to communications.
cc	To cover the door.
dd	Protection for those firing from traversing fire.

FIG. 2. SECTIONAL ELEVATION ON A-B.


Wall heightened when firestep is built
Original wall before firestep is added
+8'0"
+6'6"
+4'6"
d
a
a
a
d

In this diagram traversing is not shewn so that parados aaa may be clearly seen. The tent is pitched over the walls so that grenades will roll off it.

TYPES OF BLOCKHOUSES.

FIG. 1.

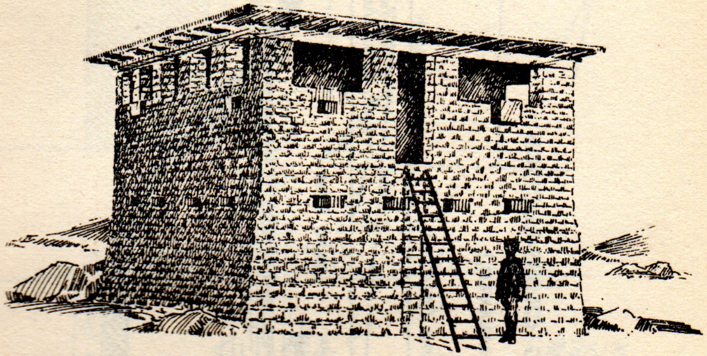
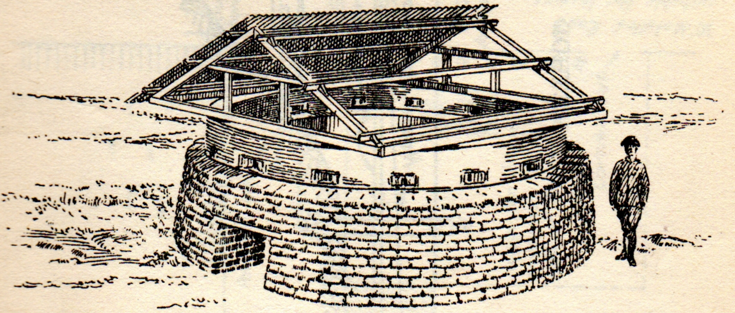
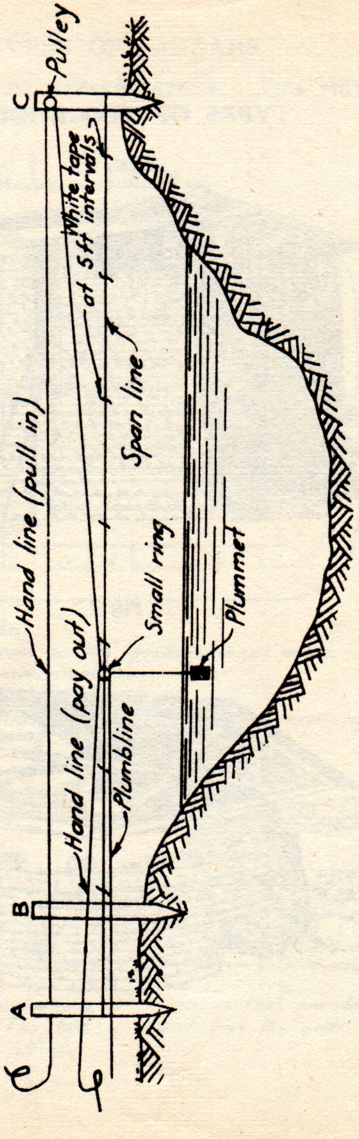


FIG 2.

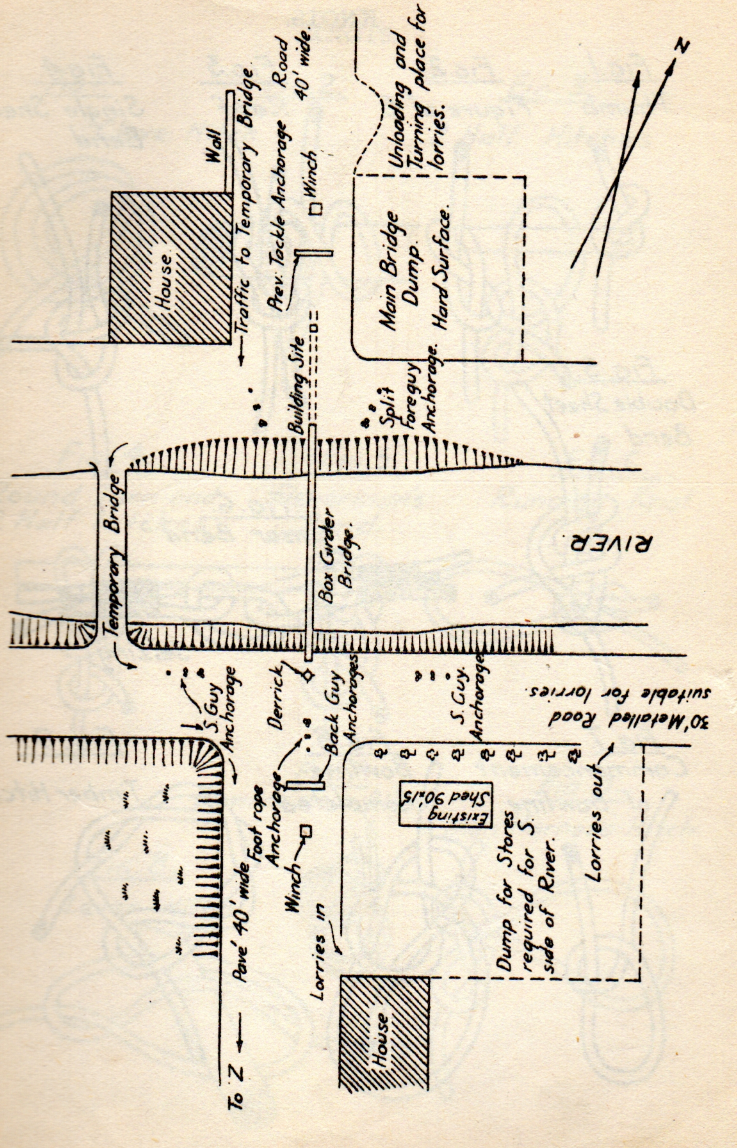


METHOD OF TAKING CROSS-SECTION.

(NO BOAT AVAILABLE.)


Pulley
C
White tape at 5ft intervals
Span line
Hand line (pull in)
Small ring
Plummet
Hand line (pay out)
Plumbline
B
A

ORGANIZATION OF WORK AT A BRIDGE SITE.


Wall
Traffic to Temporary Bridge
Road 40' wide.
Prev: Tackle Anchorage
Winch
Unloading and Turning place for lorries.
N
House
Building Site
Main Bridge Dump.
Hard Surface.
Split Foreguy Anchorage.
RIVER
Temporary Bridge
Box Girder Bridge.
S. Guy Anchorage
Derrick
Back Guy Anchorages
S. Guy. Anchorage
30' Metalled Road suitable for lorries.
Existing Shed 90'x15
Foot rope Anchorage
Winch
Pavé 40' wide
Lorries in
Lorries out
Dump for Stores required for S. side of River.
House
To Z

KNOTS.

FIG. 1.
Thumb

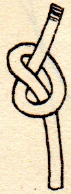


FIG. 2.
Figure of 8

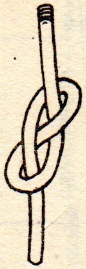


FIG. 3
Reef

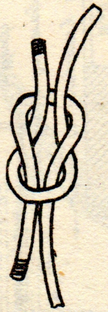


FIG. 4.
Single Sheet Bend

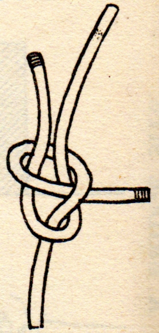


FIG. 5.
Double Sheet Bend

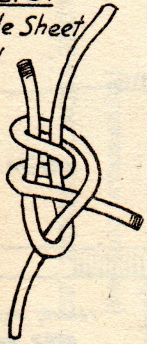


FIG. 6.
Hawser Bend

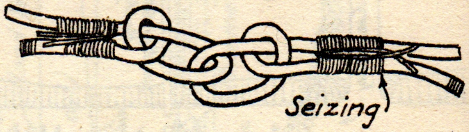


FIG. 7.
Commencement of Bowline.

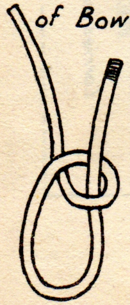


FIG. 8.
Bowline Completed

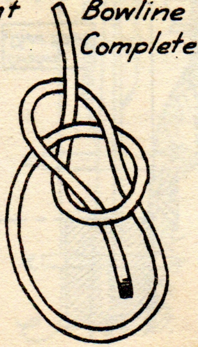
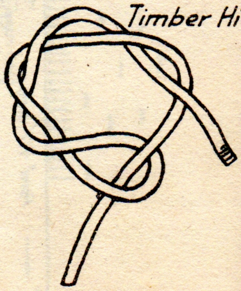


FIG. 9.
Timber Hitch



KNOTS.

FIG. 1.

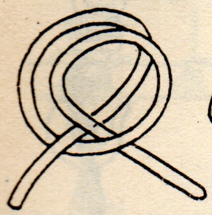


FIG. 2.
Clove Hitch

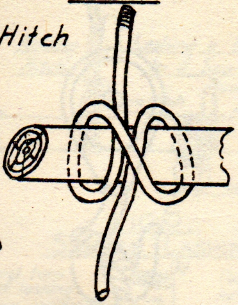


FIG. 3.
2 Half Hitches

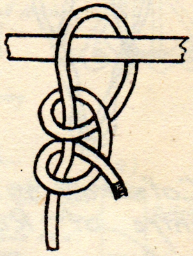


FIG. 4.
Round Turn and 2 Half Hitches

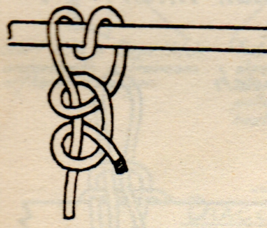


FIG. 5.
Fisherman's Bend.

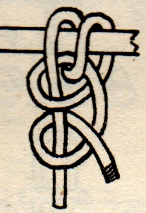


FIG. 6.
Running Knot.

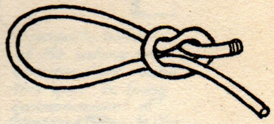


FIG. 7.
Bowline on a Bight

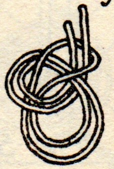


FIG. 8.
Lever Hitch

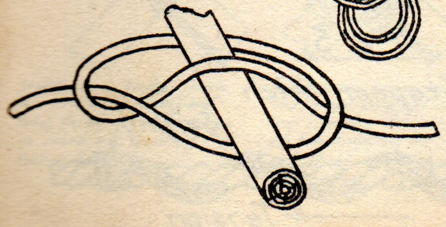
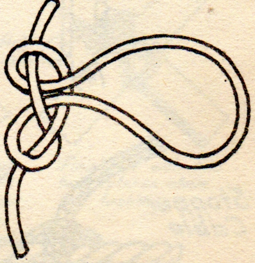
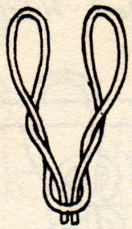


FIG. 9.
Man Harness Hitch.



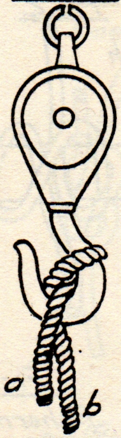
KNOTS.

Fig. 1.



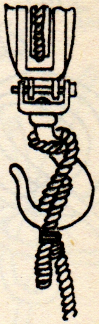
Cat's Paw on Centre of Rope

Fig. 2.



Single Blackwall Hitch

Fig 3.



Double Blackwall Hitch

Fig. 4.

Draw Hitch

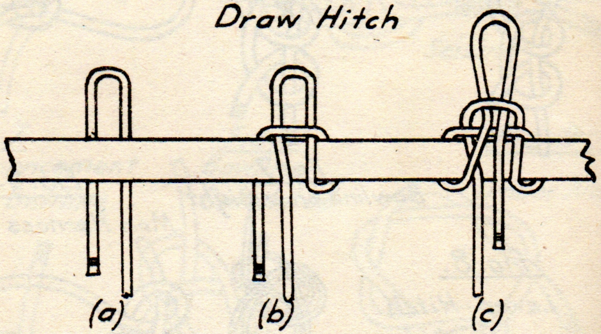
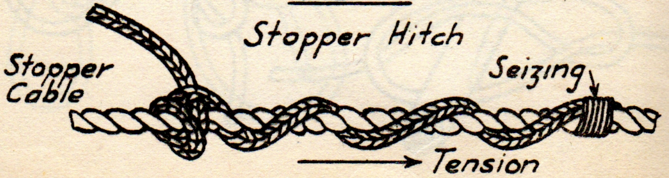


Fig. 5.

Stopper Hitch


Stopper Cable
Seizing
Tension

KNOTS AND LASHINGS.

Fig. 1. Fig. 2. Fig. 3. Fig. 4.

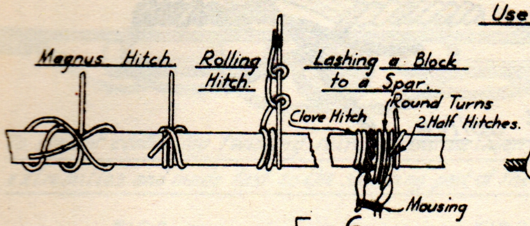

Magnus Hitch.
Rolling Hitch.
Lashing a Block to a Spar.
Clove Hitch
Round Turns
2 Half Hitches.
Mousing

Fig. 5.

Use of Selvagee.

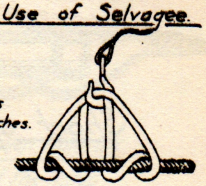
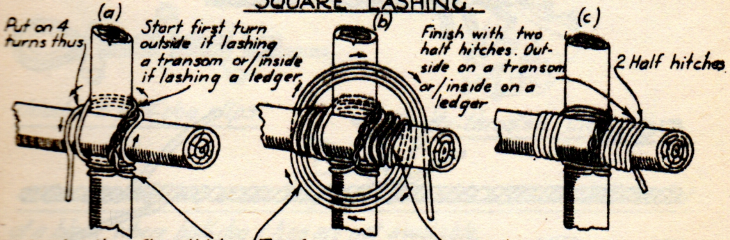


Fig. 6.

Square Lashing.


(a)
(b)
(c)
2 Half hitches

Put on 4 turns thus

Start first turn outside if lashing a transom or/inside if lashing a ledger.

Finish with two half hitches. Outside on a transom or/inside on a ledger

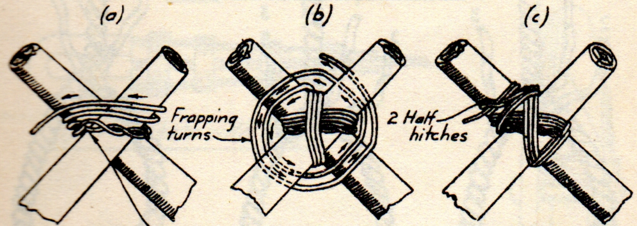
Start with a Clove Hitch underneath a Transom or/Above a Ledger.

Two frapping turns shown loose for clearness these to be pulled up tight and beaten in.

4 complete turns of the lashing and an extra turn round this spar to bring commencement of frapping turns to the right place.

Fig. 7.

Diagonal Lashing.


(a)
(b)
(c)
Frapping turns
2 Half hitches

Start with a timber hitch (or a running bowline) and take three complete turns as above not counting the timber hitch.

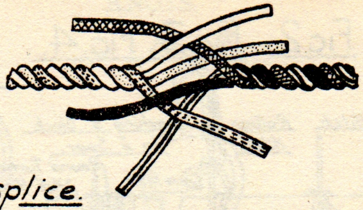
Take three turns across the other diagonal working towards the left; put on two frapping turns; pull these up tight and beat them in

Finish off with two half hitches above the lashing.

[*Ref. Sec.* 53, 4.

SPLICING.

FIG. 1.



Short splice.

FIG. 2.

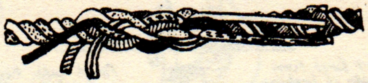
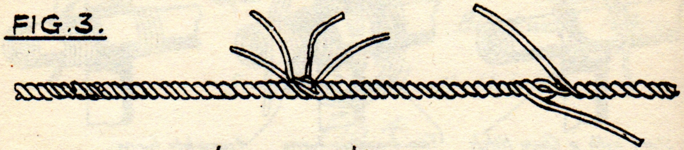


FIG. 3.



Long splice.

FIG. 4.

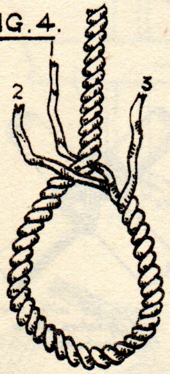


FIG. 5.

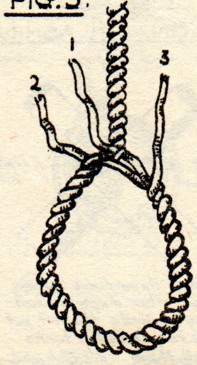
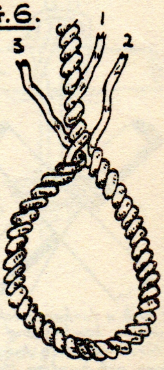


FIG. 6.



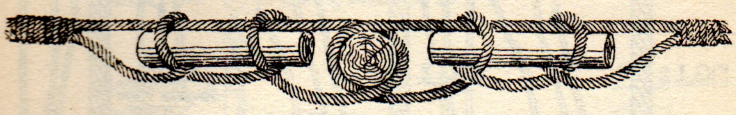
Forming eye splice.

Back View.

Ref. Secs. 54, 3 *ond* 55, 4.]

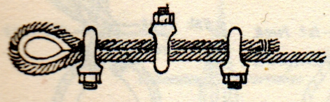
WIRE ROPE ATTACHMENTS.

FIG 1.



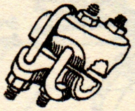
To prevent centre log twisting, reins should be taken from the extremities and made fast to the standing part of the ropes

FIG 2



Thimble & Bull-dog clips

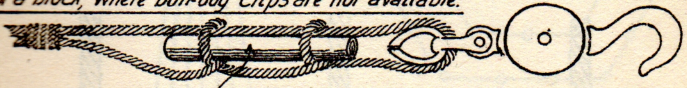
FIG. 3.



Double-throated Clamp.

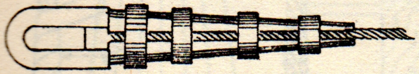
FIG 4

Alternative method of attaching with a thimble & shackle to the becket of a block, where bull-dog clips are not available.



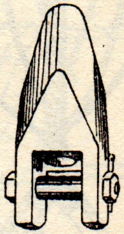
Dia of Spar at least 4 times circumference of Rope

FIG. 5.



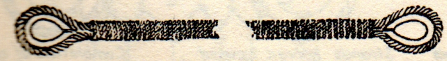
Split Sockets with Rings.

FIG. 6.



Solid Sockets.

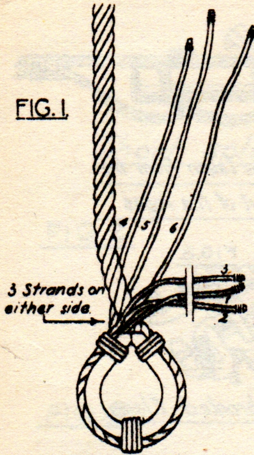
FIG. 7.



Wire Rope Strop

EYE SPLICE IN WIRE ROPE.

FIG. 1.


4
5
6
3
1
2
3 Strands on either side.

S.W.R. fastened to thimble in three places.

FIG. 2.

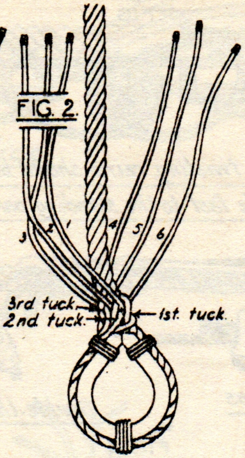
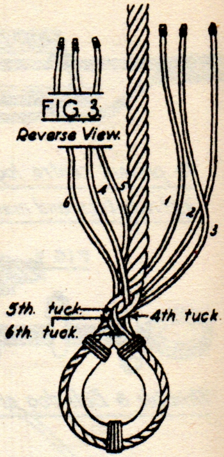

3
2
1
4
5
6
3rd tuck.
2nd tuck.
1st. tuck.

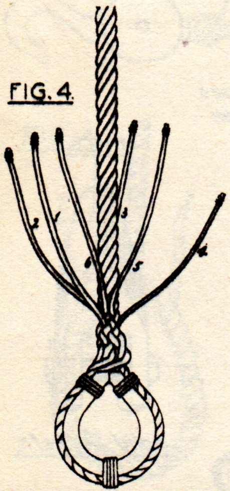
FIG. 3.

Reverse View.


6
4
5
1
2
3
5th. tuck.
6th. tuck.
4th. tuck.

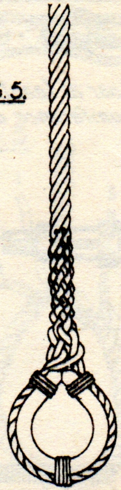
One complete Round.

FIG. 4.



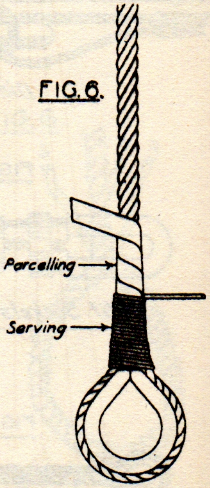
Core removed from strands at second round.

FIG. 5.



Strands halved, tapered and finished off.

FIG. 6.


Parcelling
Serving

Completion of splice

MAKING WIRE ROPES.

FIG. 3.

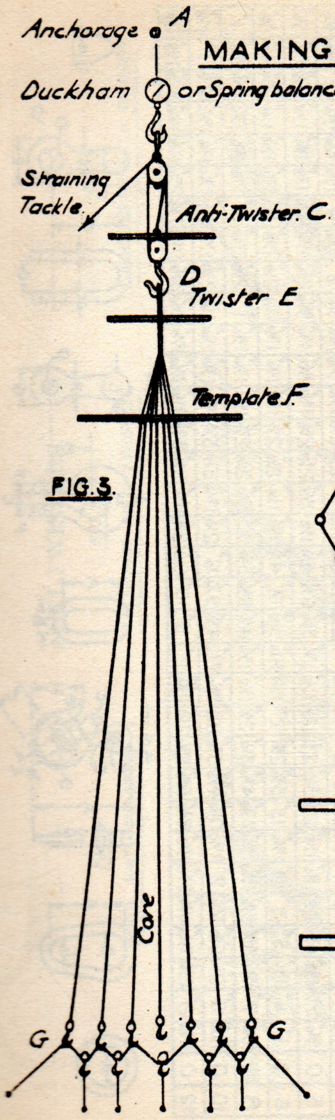

Anchorage
A
Duckham
or Spring balance. B
Straining Tackle.
Anti-Twister. C
D
Twister E
Template F.
Core
G
G

FIG. 1.

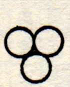


FIG. 2.

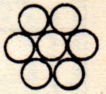


FIG. 4.

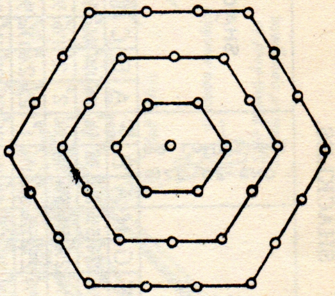
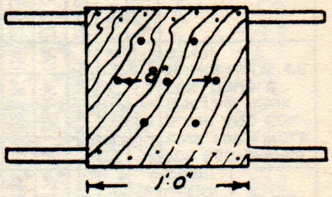


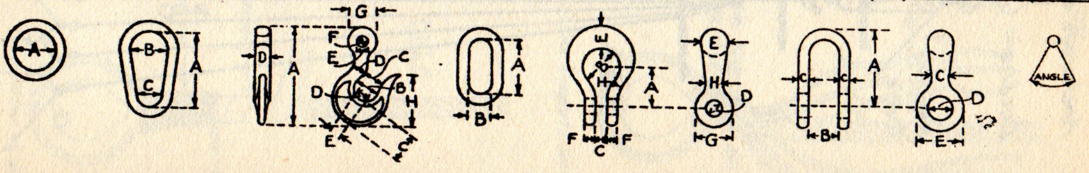
FIG. 5.



TEMPLATE

STRENGTHS AND STANDARD DIMENSIONS OF HOOKS, RINGS, LINKS AND SHACKLES.

WORKING LOAD.		SIZE OF CHAIN.	RINGS.		TOP EGG-SHAPED LINK FOR SINGLE SLING AND CONNECTING LINK FOR DOUBLE SLING, HOOK OR RING.				HOOKS.								SIZE OF END OR LONG LINKS.			SHACKLES.								STRAIGHT SHACKLES.					SIZE OF DOUBLE SLING CHAIN.	
TONS.	CWTS.		INTERNAL DIAMETER 'A'.	DIAMETER OF IRON.	A	B	C	DIA OF IRON	A	B	C	D	E	F	G	H	A	B	DIA OF IRON	A	B	C	D	E	F	G	H	A	B	C DIA OF IRON	D	E	45°	90°
1	10	1/2"	4"	1"	2 9/16"	1 1/2"	3/4"	11/18"	6 1/2"	1 7/8"	1 7/16"	1"	5/8"	11/16"	1 3/4"	3 1/2"	2 1/4"	7/8"	5/8"	1 1/4"	1 1/4"	13/16"	5/8"	11/16"	7/16"	1 1/4"	9/16"	2 1/2"	13/16"	11/16"	5/8"	1 1/4"	7/16"	7/16"
3	0	3/4"	5"	1 5/16"	3 11/16"	2 1/4"	1 1/8"	1"	9 3/4"	2 3/4"	2 1/16"	1 1/2"	7/8"	1 1/16"	2 5/8"	5 1/4"	3 3/8"	1 1/4"	15/16"	2"	2"	1 1/8"	7/8"	1 1/8"	11/16"	1 7/8"	7/8"	3 3/4"	1 1/8"	1"	7/8"	1 7/8"	9/16"	11/16"
4	0	1 3/16"	5"	1 7/16"	4"	2 7/16"	1 1/4"	1 1/16"	10 5/16"	3"	2 1/4"	1 5/8"	15/16"	1 1/8"	2 13/16"	5 11/16"	3 3/4"	1 3/8"	1"	2 1/8"	2 1/8"	1 3/16"	15/16"	1 3/16"	3/4"	2"	15/16"	4"	1 3/16"	1 1/16"	15/16"	2"	5/8"	3/4"
5	0	1 5/16"	5 1/2"	1 5/8"	4 3/4"	2 13/16"	1 7/16"	1 1/4"	12 1/8"	3 1/2"	2 9/16"	1 7/8"	1 1/8"	1 3/8"	3 1/4"	6 9/16"	4 1/4"	1 1/2"	1 1/8"	2 3/8"	2 3/8"	1 3/8"	1 1/8"	1 5/16"	13/16"	2 3/16"	1 1/16"	4 3/4"	1 3/8"	1 1/4"	1 1/8"	2 3/16"	3/4"	13/16"
6	0	1"	6"	1 3/4"	5"	3"	1 1/2"	1 5/16"	13"	3 3/4"	2 3/4"	2"	1 1/4"	1 7/16"	3 1/2"	7"	4 1/2"	1 5/8"	1 1/4"	2 1/2"	2 1/2"	1 7/16"	1 1/4"	1 3/8"	13/16"	2 1/4"	1 1/8"	5"	1 7/16"	1 5/16"	1 1/4"	2 1/4"	3/4"	7/8"
8	0	1 3/16"	7"	2 1/16"	5 3/4"	3 9/16"	1 13/16"	1 9/16"	15 7/16"	4 7/16"	3 1/4"	2 3/16"	1 1/2"	1 11/16"	4 1/8"	8 5/16"	5 3/8"	2"	1 7/16"	2 7/8"	2 7/8"	1 11/16"	1 7/16"	1 9/16"	1"	2 5/8"	1 5/16"	6"	1 11/16"	1 9/16"	1 7/16"	2 5/8"	15/16"	1"
10	0	1 5/16"	8"	2 1/4"	6 1/2"	3 15/16"	2"	1 11/16"	17 1/16"	4 7/8"	3 5/8"	2 5/8"	1 11/16"	1 13/16"	4 9/16"	9 3/16"	6"	2 1/4"	1 9/16"	3 1/8"	3 1/8"	1 13/16"	1 9/16"	1 11/16"	1 1/8"	2 7/8"	1 7/16"	6 1/2"	1 13/16"	1 3/4"	1 9/16"	2 7/8"	1"	1 1/8"
12	0	1 7/16"	8"	2 7/16"	7 1/16"	4 5/16"	2 3/16"	1 7/8"	18 5/8"	5 3/8"	3 15/16"	2 7/8"	1 13/16"	2"	5"	10"	6 1/2"	2 3/8"	1 3/4"	3 9/16"	3 3/8"	2 1/16"	1 11/16"	1 7/8"	1 3/16"	3 1/8"	1 9/16"	7 1/4"	2 1/16"	1 7/8"	1 11/16"	3 1/8"	1 1/8"	1 1/4"

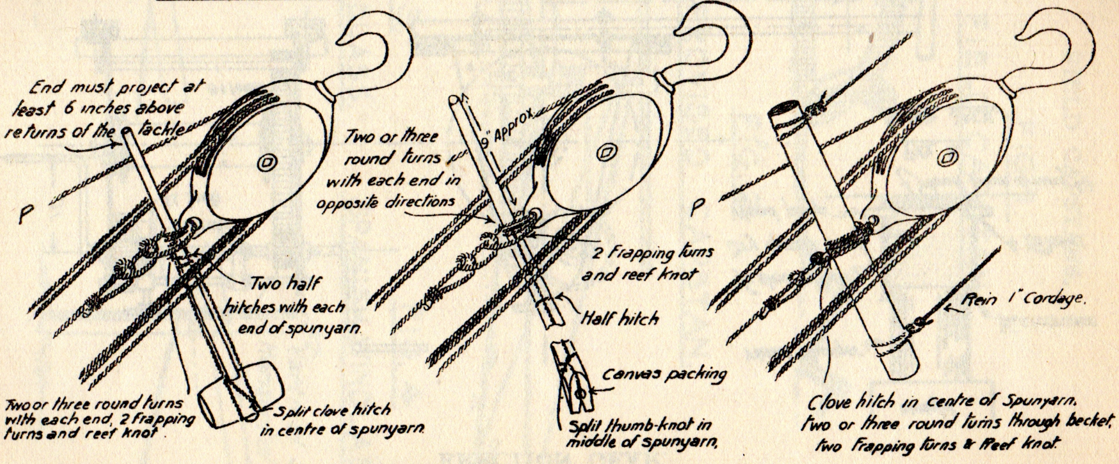

A
B
C
A
D
A
G
F
E
D
C
B
H
D
E
C
A
B
E
A
F
C
F
E
H
D
G
C
C
A
B
C
D
E
ANGLE

ANTI-TWISTERS.

FIG. 1.
MAUL ANTI-TWISTER.

FIG. 2.
CROWBAR ANTI-TWISTER.

FIG. 3.
LIGHT SPAR WITH REINS.


End must project at least 6 inches above returns of the tackle
P
Two half hitches with each end of spunyarn.
Two or three round turns with each end, 2 frapping turns and reef knot.
Split clove hitch in centre of spunyarn.
9" Approx.
Two or three round turns with each end in opposite directions
2 Frapping turns and reef knot
Half hitch
Canvas packing
Split thumb-knot in middle of spunyarn,
P
Rein 1" Cordage.
Clove hitch in centre of Spunyarn, two or three round turns through becket, two Frapping turns & Reef knot.

ERECTION GEAR.

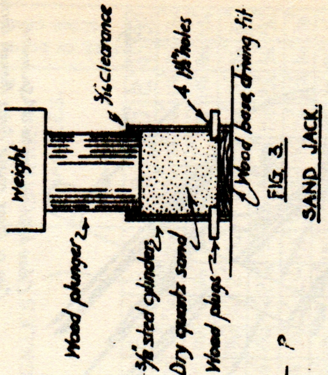

Weight
3/16 clearance
4 1/8" holes
Wood base, driving fit
Wood plungers
3/16 steel cylinder
Dry quartz sand
Wood plugs

FIG. 3.
SAND JACK.

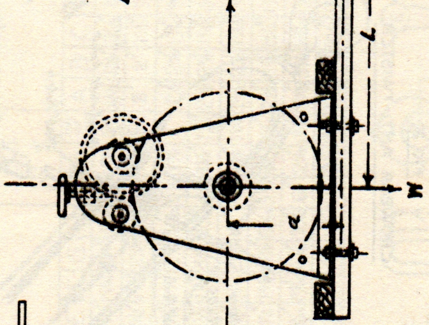


FIG. 2.
BASE TIMBERS FOR WINCH.

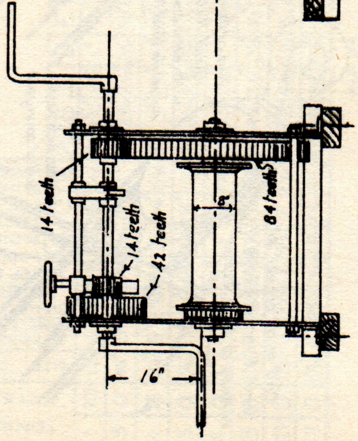

14 teeth
14 teeth
42 teeth
84 teeth
16"

FIG. 1.
WINCHES.

FIELD CAPSTANS.

FIG. 1.
FIELD CAPSTAN.

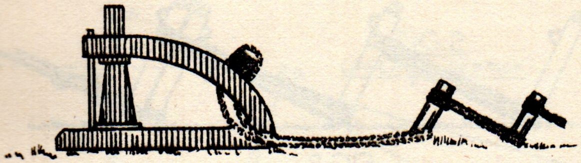


FIG. 2.
IMPROVISED CAPSTAN.

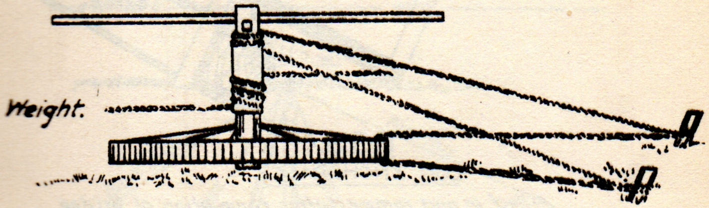


FIG. 3.
SPANISH WINDLASS.

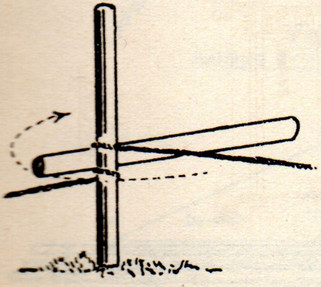
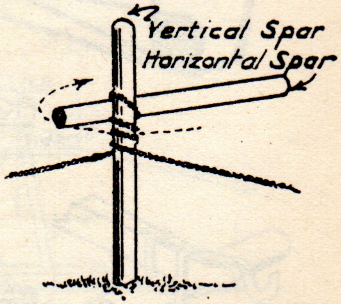


FIG. 4.
SPANISH WINDLASS.


Vertical Spar
Horizontal Spar

HOLDFASTS AND ANCHORAGES.

FIG.1.

3.2.1 PICKET HOLDFAST.

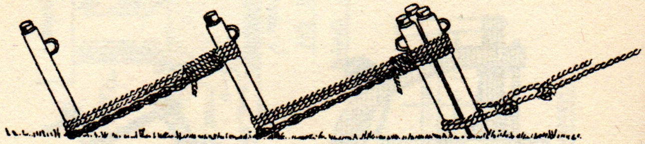


FIG.2.

BAULK HOLDFAST.

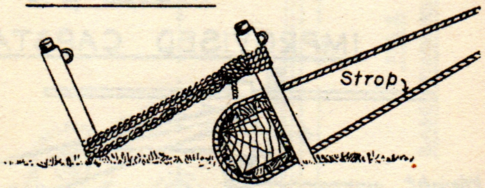


FIG.3.

LOG ANCHORAGE

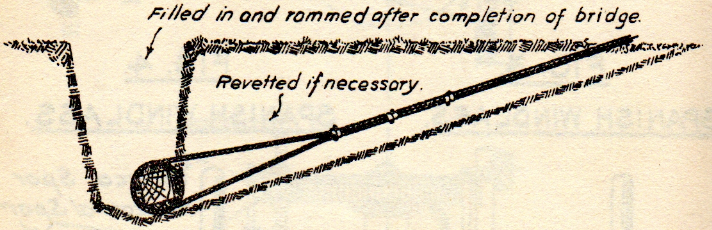
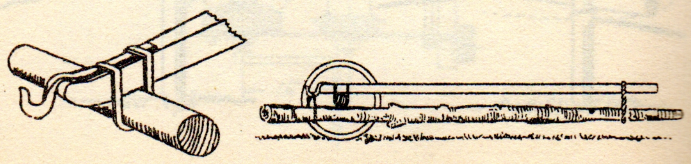

Filled in and rammed after completion of bridge.
Revetted if necessary.

FIG.4.

DEVIL CART.



DERRICKS.

FIG.1.

MARKING OUT GROUND FOR DERRICK.

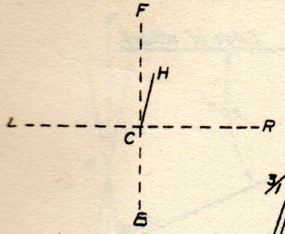


FIG.2.

LOWERING DERRICK.

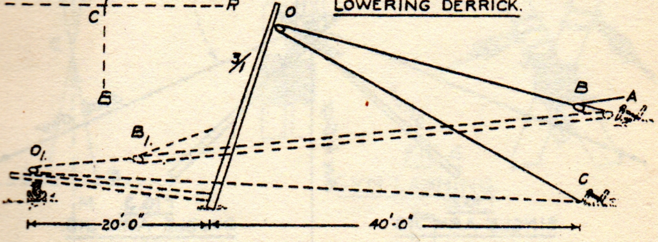

O
3/1
B
A
B1
O1
C
20'·0"
40'·0"

FIG.3.

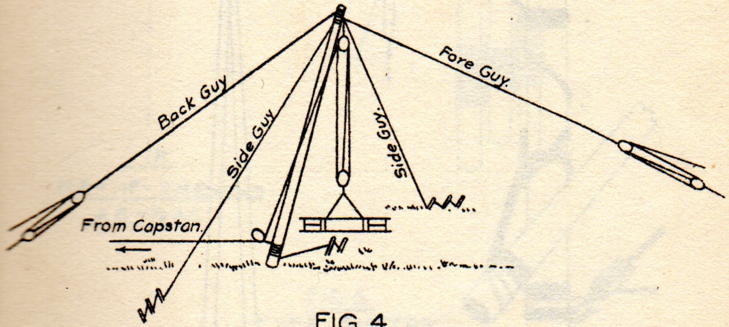
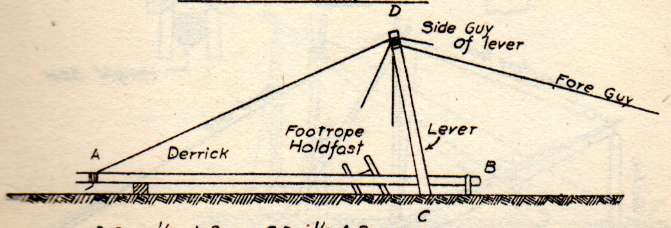

Back Guy
Side Guy
Side Guy
Fore Guy
From Capstan

FIG.4.

RAISING BY MOVING LEVER.


D
Side Guy of lever
Fore Guy
Footrope Holdfast
Lever
A
Derrick
B
C

BC = 1/4 AB.   CD = 1/2 AB

SWINGING DERRICKS.

FIG. 1.

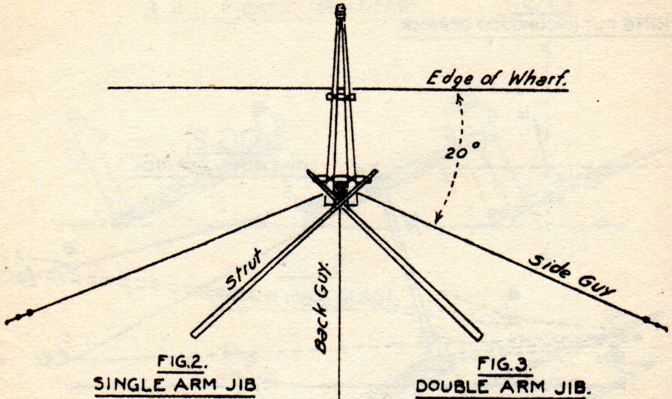

Edge of Wharf.
20°
Strut
Back Guy.
Side Guy

FIG. 2.
SINGLE ARM JIB

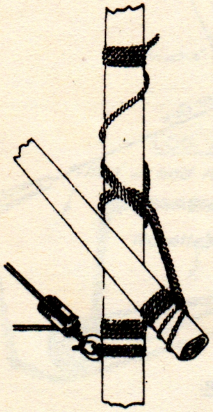


FIG. 3.
DOUBLE ARM JIB.

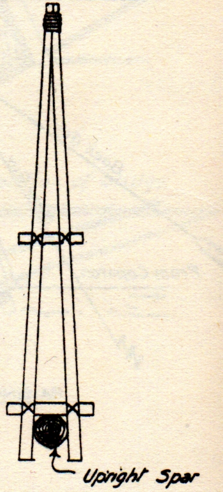
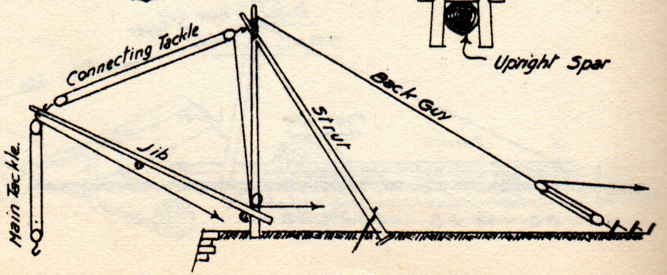
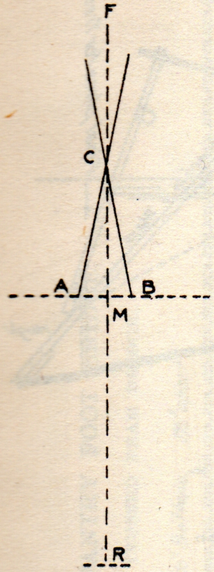

Upright Spar

FIG 4.


Connecting Tackle
Back Guy
Strut
Jib
Main Tackle.

SHEERS AND GYNS.

FIG. 1.
LAYING OUT SHEERS



M.R – MF – 2MC

AB – 1/3 AC.

SHEERS LASHING.

FIG 2

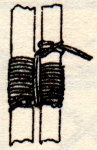


FIG 3

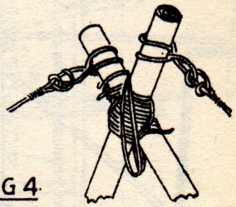


FIG 4.
GYN LASHING.

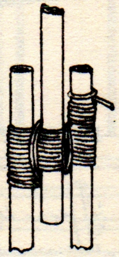
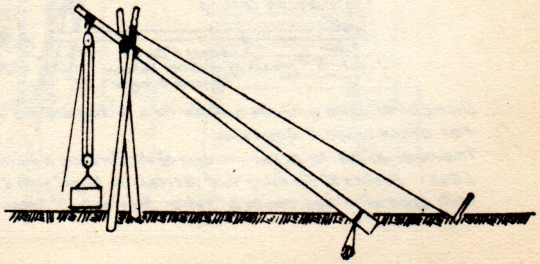


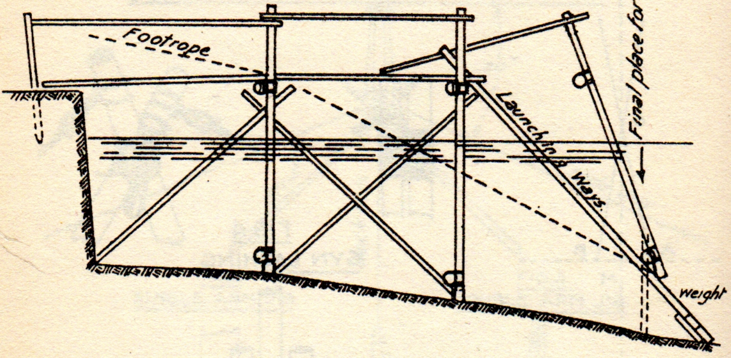
FIG 5.
LEVER SHEERS.



TRESTLES.

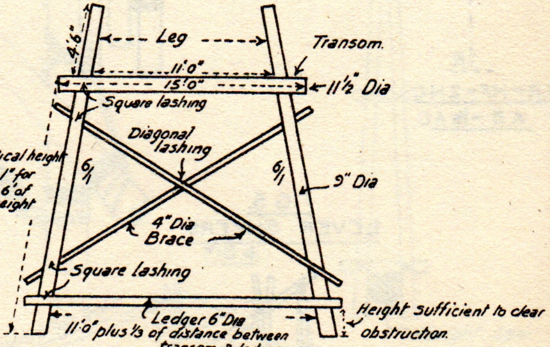
METHOD OF LAUNCHING.

FIG. 1


Footrope
Launching Ways.
Final place for Trestle
Weight

LASHED SPAR TRESTLE.

FIG. 2.


4'6"
Leg
Transom.
11'0"
15'0"
11½" Dia
Square lashing
Diagonal lashing
Vertical height plus 1" for each 6' of height
6/1
6/1
9" Dia
4" Dia Brace
Square lashing
Ledger 6" Dia
11'0" plus ⅓ of distance between transom & ledger
Height sufficient to clear obstruction.

Diameter of spars given are suitable for a 15' bay and a 15' height of Trestle.

FOR OTHER SPANS & HEIGHTS:

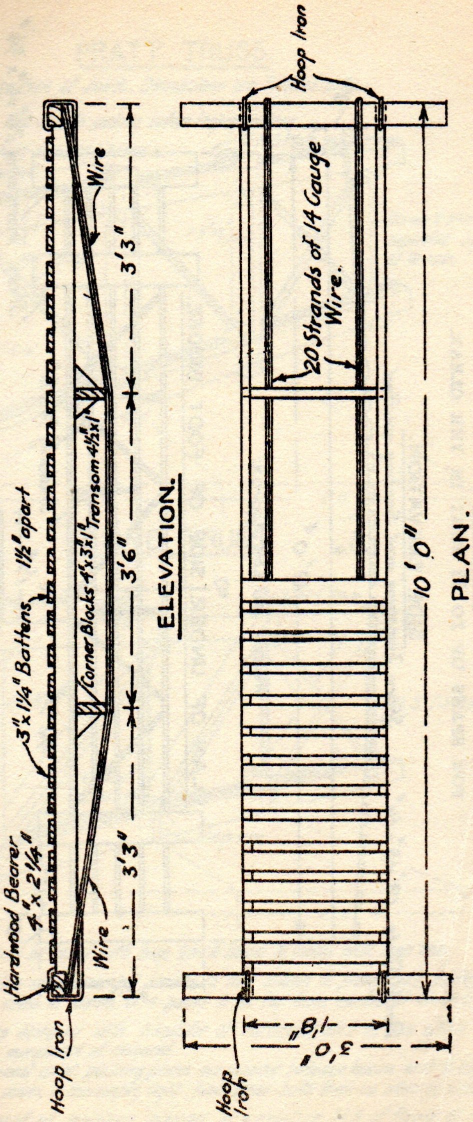
TRANSOM: 10" Dia for 10' bay increase ½" dia. for every 2' increase in span of bay

LEGS: Reduce ½" for every foot decrease in height with 6 inch minimum.

With span of 10' legs can be ½" lighter than with 15' spans

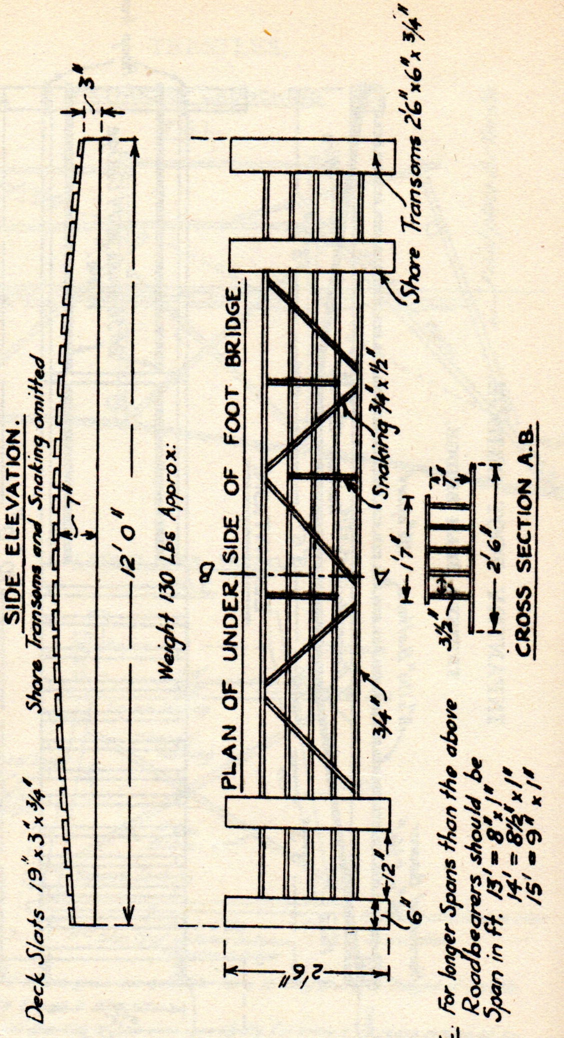
INFANTRY FOOT BRIDGE.

TRUSSED BEAM BRIDGE.


Wire
3'3"
3'6"
3'3"
Corner Blocks 4"x3"x1¼"
Transom 4½"x1"
3"x1¼" Battens 1½" apart
Hardwood Bearer 4"x2¼"
Wire
Hoop Iron
ELEVATION.
Hoop Iron
20 Strands of 14 Gauge Wire.
10'0"
PLAN.
1'8"
3'0"
Hoop Iron

INFANTRY FOOT BRIDGE.

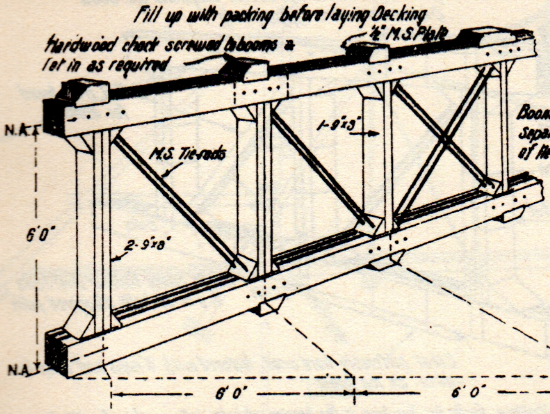
FOR SPANS UP TO 11 FEET IN THE CLEAR.


SIDE ELEVATION.
Shore Transoms and Snaking omitted
Deck Slats 19" x 3" x 3/4"
3"
7"
12' 0"
Weight 130 Lbs Approx:
PLAN OF UNDER SIDE OF FOOT BRIDGE.
B
A
Shore Transoms 2' 6" x 6" x 3/4"
Snaking 3/4" x 1/2"
3/4"
12"
6"
2' 6"
1' 1"
7"
3 1/2"
2' 6"
CROSS SECTION A.B.

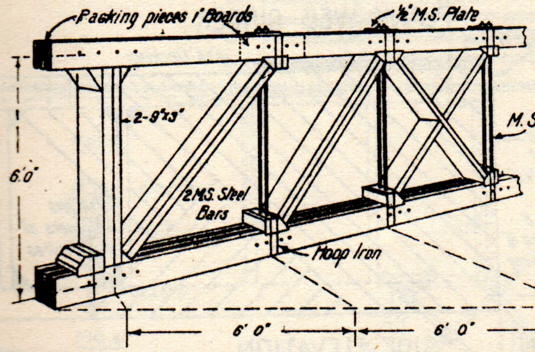
NOTE. For longer Spans than the above Roadbearers should be
Span in ft. 13' = 8" x 1"
14' = 8 1/2" x 1"
15' = 9" x 1"

PRATT TRUSS.

Showing Type of Joints. Dimensions are Typical only.


Fill up with packing before laying Decking
Hardwood chock screwed to booms & let in as required
1/2" M.S. Plate
N.A.
M.S. Tie-rods
1-9" x 3"
Booms 3-9" x 3" Separated by diam. of tie rods.
6' 0"
2-9" x 8"
N.A.
6' 0"
6' 0"

HOWE TRUSS.


Packing pieces 1" Boards
1/2" M.S. Plate
2-9" x 3"
M.S. Tie Rods.
6' 0"
2 M.S. Steel Bars
Hoop Iron
6' 0"
6' 0"

(1) Struts should be bound with hoop iron & bound to booms with hoop iron.

(2) Flange Splice not shown but similar to that shown in plank web Girder (Pl. 92) Splices to come in centre of a panel & as far from centre of Girder as possible.

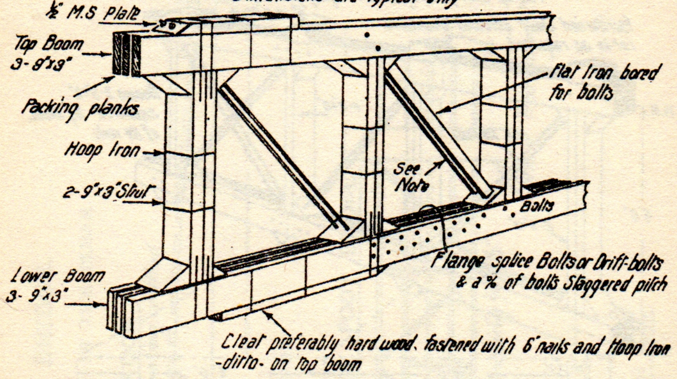
(3) Chocks are designed with Shoulder of sufficient size to take whole horizontal component of diagonal.

(4) At each panel point packing pieces are inserted between booms and 4 bolts used to make a thoroughly rigid joint; these bolts have no other function.

(5) Centre lines of all members intersect at a point on N.A. of flange at each joint.

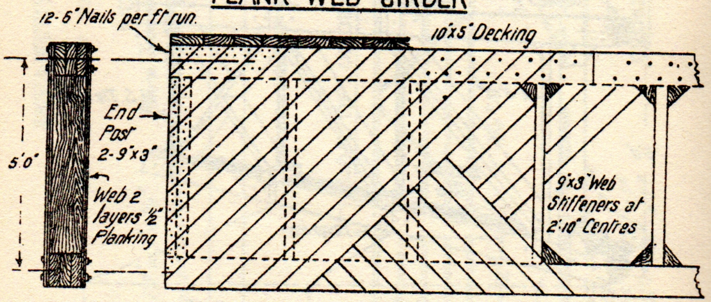
PRATT TRUSS.

Showing alternative types of joints where double diagonals are used
Dimensions are typical only


½" M.S Plate
Top Boom 3-9"x3"
Packing planks
Hoop Iron
2-9"x3" Strut
Lower Boom 3-9"x3"
Flat Iron bored for bolts
See Note
Bolts
Flange splice Bolts or Drift-bolts & a % of bolts Staggered pitch
Cleat preferably hard wood. fastened with 6" nails and Hoop Iron -ditto- on top boom

Note The limiting factor for this type is the bearing of bolts into wood & it will be found that this method can only be used in the case of lightly stressed diagonals.

PLANK WEB GIRDER


12-6" Nails per ft run.
10"x5" Decking
5'0"
End Post 2-9"x3"
Web 2 layers ½" Planking
9"x3" Web Stiffeners at 2'10" Centres

END ELEVATION   SIDE ELEVATION

Suitable for 8 Ton axles, Span 60' Four girders.

NOTE (1.) The ¾" bolts can be continued throughout and will then serve the double purpose of fastening web to booms and splicing booms.

(2.) Web can be reduced to two ½" planks for centre 20' of girder.

Boom joint ¾" bolts 5½" pitch. 12 each side. All except 10% can be plain drift bolts unless used to fasten web as well.

COMMON SUSPENSION BRIDGE.

FIG. 1.

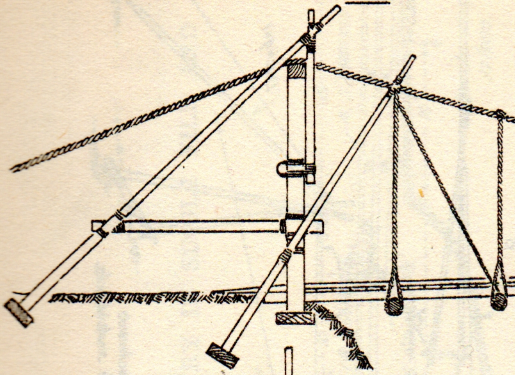


FIG. 2.

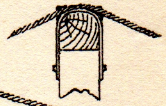


FIG. 3.

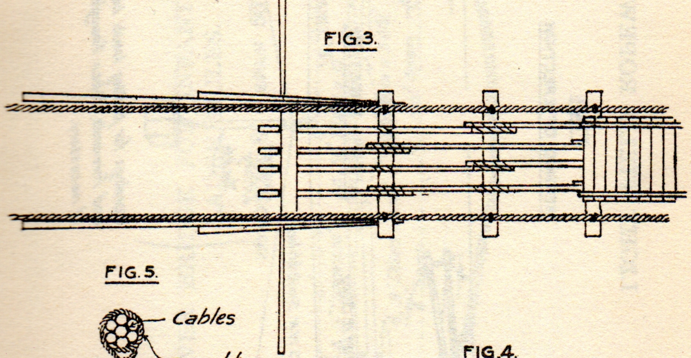


FIG. 5.

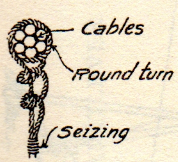

Cables
Round turn
Seizing

FIG. 6.

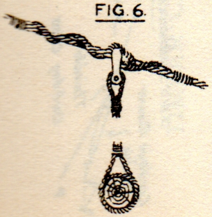
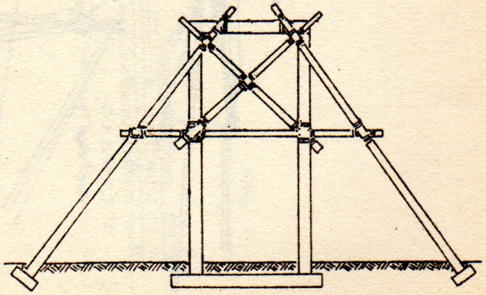


FIG. 4.



LIGHT FIELD ROPEWAY.

FIG.1.

METHOD OF ERECTION

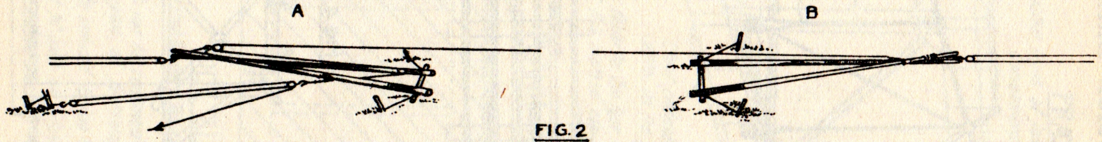
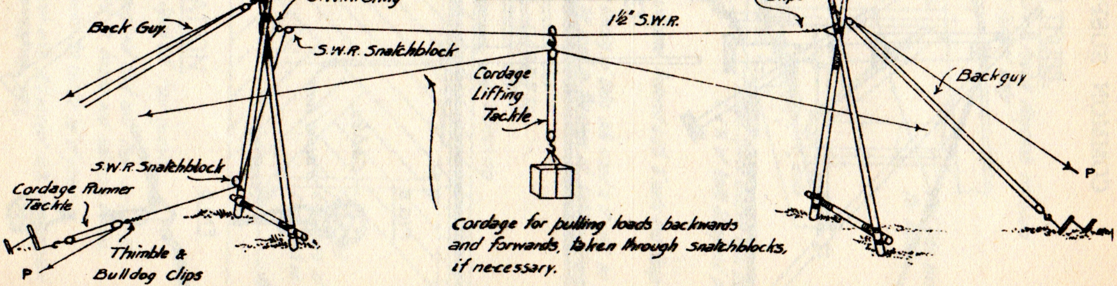


FIG. 2

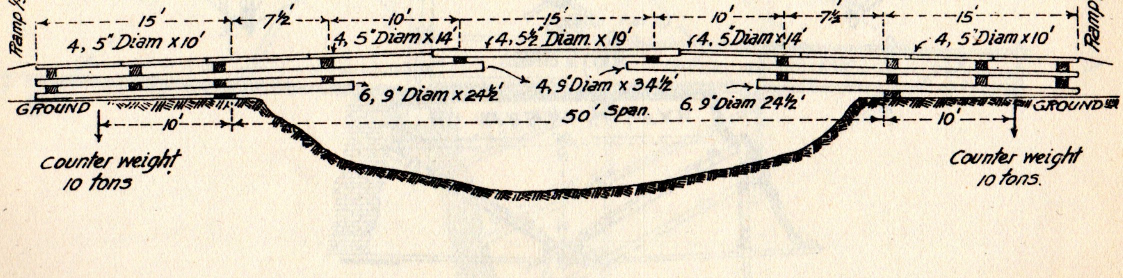
AFTER ERECTION


S.W.R. Sling
Back Guy.
S.W.R. Snatchblock
Cordage Lifting Tackle
1½" S.W.R.
3 Bulldog Clips
Backguy
P
S.W.R. Snatchblock
Cordage Runner Tackle
Thimble & Bulldog Clips
P

Cordage for pulling loads backwards and forwards, taken through snatchblocks, if necessary.

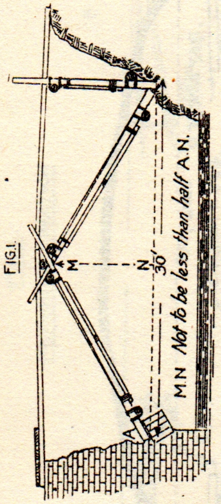
TIMBER CANTILEVER BRIDGE FOR INFANTRY IN SINGLE FILE AND LADEN MULES.

ROADWAY 6′. SPAN 50′.


Ramp 1/5
15′
7½′
10′
15′
10′
7½′
15′
Ramp 1/5
4, 5" Diam x 10′
4, 5" Diam x 14′
4, 5½" Diam. x 19′
4, 5" Diam x 14′
4, 5" Diam x 10′
6, 9" Diam x 24½′
4, 9" Diam x 34½′
6, 9" Diam 24½′
GROUND
50′ Span.
GROUND
10′
10′
Counter weight 10 tons
Counter weight 10 tons.

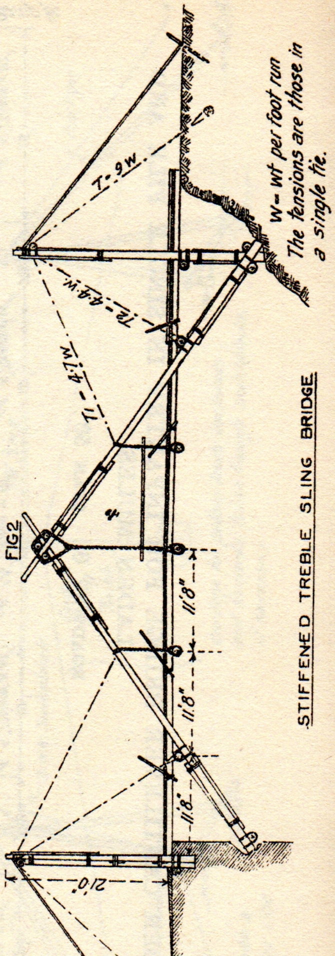
FRAME BRIDGES.

FIG.1


A
M
N
30'
MN Not to be less than half A.N.

SINGLE LOCK

FIG2

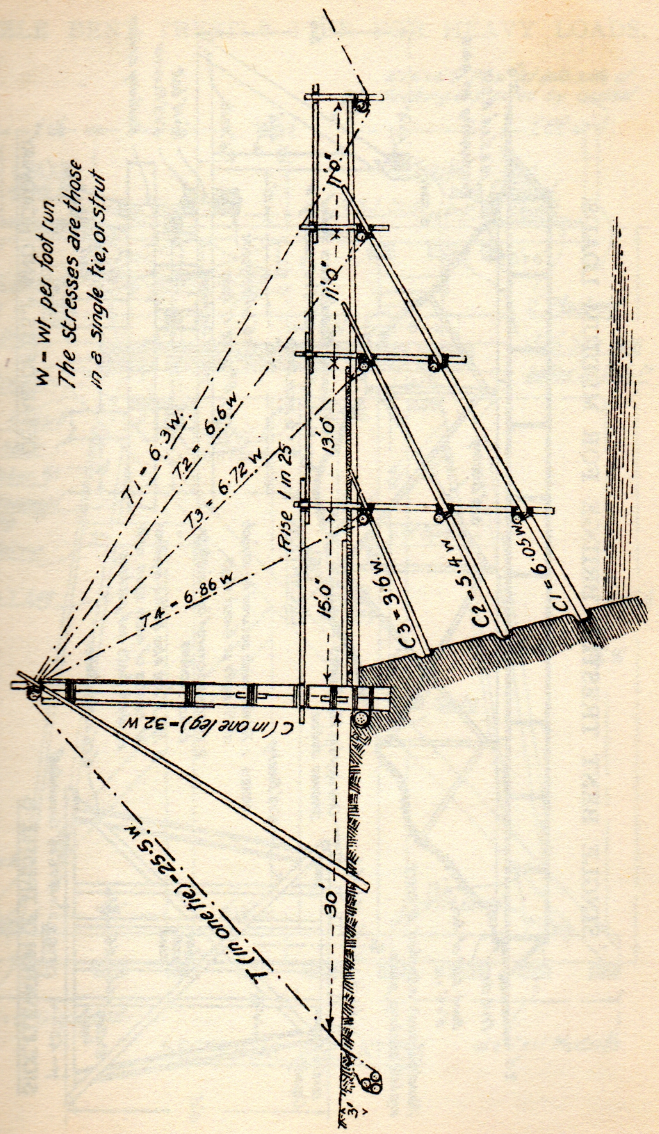

T - 9 w
T2 - 4.4 w
T1 - 4.7 w
4
11'8"
11'8"
11'8"
21'0"
T

STIFFENED TREBLE SLING BRIDGE

W - wt per foot run
The tensions are those in a single tie.

TENSION BRIDGE.

W - wt. per foot run
The stresses are those in a single tie, or strut


T1 - 6.3 W.
T2 - 6.6 w
T3 - 6.72 w
T4 - 6.86 w
Rise 1 in 25
11'0"
11'0"
13'0"
15'0"
C3 = 3.6 W.
C2 = 5.4 w
C1 = 6.05 w
C (in one leg) - 32 W
T (in one tie) - 25.5 w
30'
3'

SINGLE BENT TRESTLE BRIDGE FOR MEDIUM LOADS.

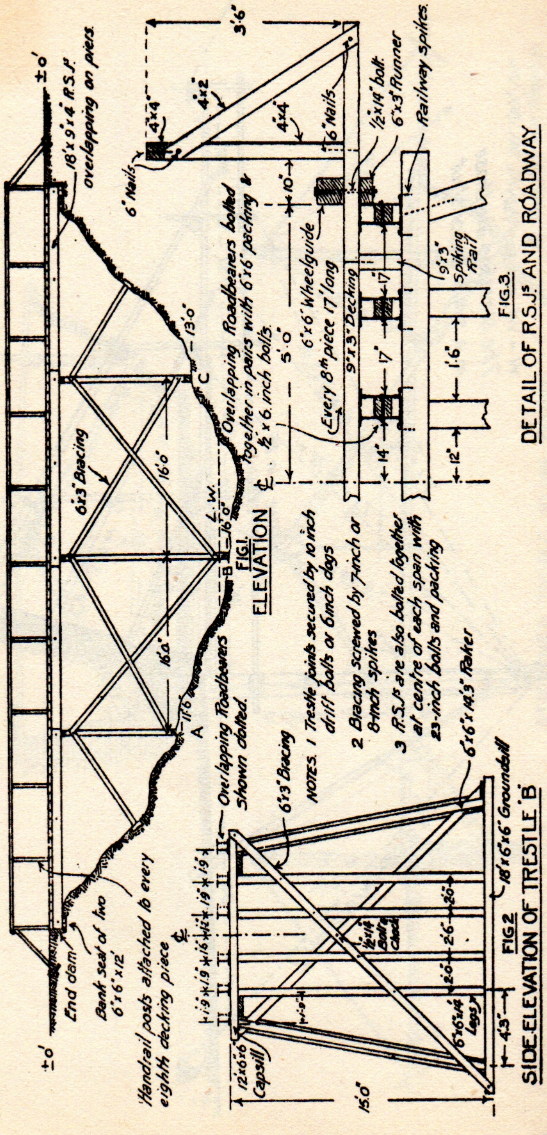

±0'
18"x9"x4' R.S.J.s overlapping on piers.
End dam
Bank seat of two 6"x6"x12'
Handrail posts attached to every eighth decking piece
6"x3" Bracing
16'0"
16'0"
13'0"
11'6"
16'0"
A
B
C
L.W.
Overlapping Roadbearers shown dotted.
6"x3" Bracing
1'9"
1'9"
1'6"
1'2"
1'9"
1'9"
2'0"
2'6"
2'0"
1'9"
½"x14" Bolt & Chock
6"x6"x14' Legs
4'3"
15'0"
12"x6"x6' Capsill
6"x6"x14.3' Raker
18'x6"x6" Groundsill
℄
3'6"
4"x4"
4"x2"
4"x4"
6" Nails
6" Nails
10"
½"x14" bolt
6"x3" Runner
Railway spikes
Overlapping Roadbearers bolted together in pairs with 6"x6" packing & ½" x 6 inch bolts.
6"x6" Wheelguide
5'0"
Every 8th piece 17' long
9"x3" Decking
17"
17"
14"
1'6"
12"
9"x3" Spiking Rail

FIG.1. ELEVATION

NOTES. 1 Trestle joints secured by 10 inch drift bolts or 6 inch dogs

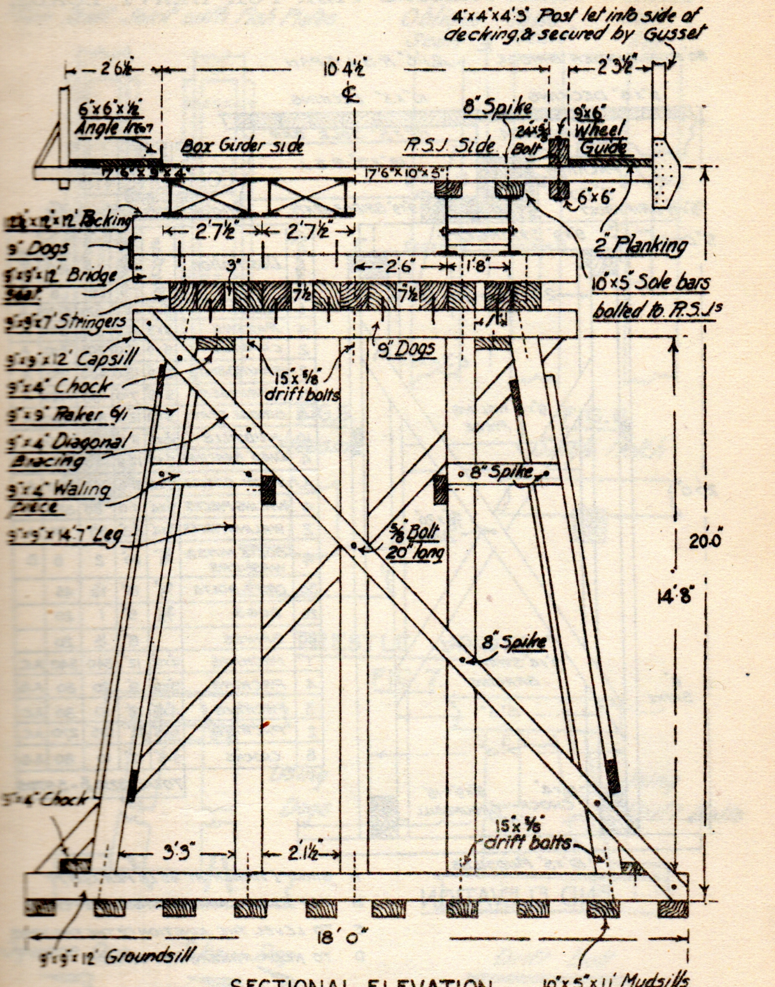
2 Bracing screwed by 7-inch or 8-inch spikes

3 R.S.J.s are also bolted together at centre of each span with 23-inch bolts and packing

FIG 2 SIDE ELEVATION OF TRESTLE 'B'

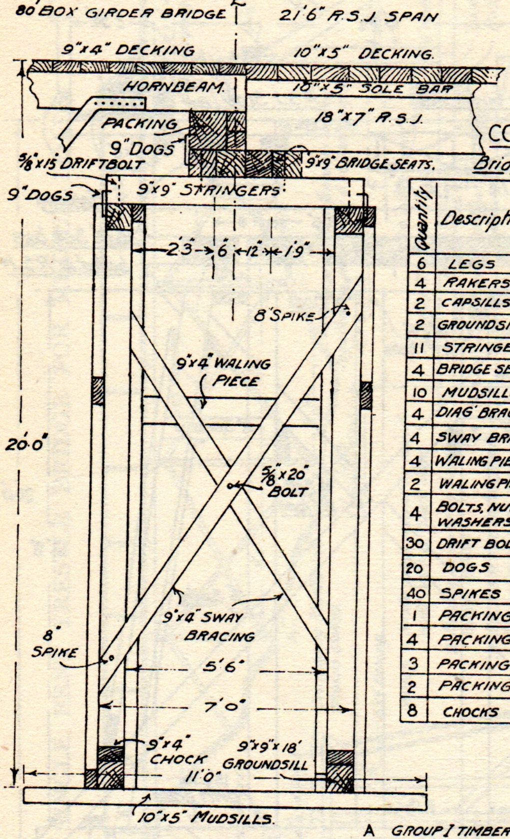
FIG.3. DETAIL OF R.S.J.s AND ROADWAY

DOUBLE BENT TRESTLE PIER FOR HEAVY LOADS.


4"x4"x4'3" Post let into side of decking, & secured by Gusset
2'6½"
10'4½"
℄
2'3½"
6"x6"x½" Angle Iron
Box Girder side
R.S.J. Side
8" Spike
2¼"x⅝" Bolt
9"x6" Wheel Guide
17'6"x9"x4"
17'6"x10"x5"
6"x6"
12"x12"x12' Packing
9" Dogs
9"x9"x12' Bridge Seat
9"x9"x7' Stringers
9"x9"x12' Capsill
9"x4" Chock
9"x9" Raker 6/1
9"x4" Diagonal Bracing
9"x4" Waling piece
9"x9"x14'7" Leg
2'7½"
2'7½"
3"
2'6"
1'8"
7½"
7½"
2" Planking
10"x5" Sole bars bolted to R.S.J.s
9" Dogs
15"x⅝" drift bolts
8" Spike
⅝" Bolt 20" long
8" Spike
20'0"
14'8"
9"x4" Chock
3'3"
2'1½"
15"x⅝" drift bolts
18'0"
9"x9"x12' Groundsill
10"x5"x11' Mudsills

SECTIONAL ELEVATION

DOUBLE BENT TRESTLE PIER FOR HEAVY LOADS.


80' BOX GIRDER BRIDGE
℄
21'6" R.S.J. SPAN
9"x4" DECKING
10"x5" DECKING.
HORNBEAM.
10"x5" SOLE BAR
18"x7" R.S.J.
PACKING
9" DOGS
5/8"x15 DRIFTBOLT
9"x9" BRIDGE SEATS.
9" DOGS
9"x9" STRINGERS
2'3"
6"
12"
1'9"
8" SPIKE
9"x4" WALING PIECE
20'0"
5/8"x20" BOLT
9"x4" SWAY BRACING
8" SPIKE
5'6"
7'0"
9"x4" CHOCK
9"x9"x18' GROUNDSILL
11'0"
10"x5" MUDSILLS.

END ELEVATION

PIER COMPONENTS
Including
Bridge seats & Mudsills

Quantity	Description.	Section	Length.	Unit Weight LB.	Total Weight LB.	Notes
6	LEGS	9"x9"	14'7"	370	2220	A
4	RAKERS	9"x9"	14'9"	375	1500	A
2	CAPSILLS	9"x9"	12'0"	305	610	A
2	GROUNDSILLS	9"x9"	18'0"	455	910	A
11	STRINGERS	9"x9"	7'0"	180	1980	A
4	BRIDGE SEATS	9"x9"	12'0	305	1220	A
10	MUDSILLS	10"x5"	11'0"	170	1770	A
4	DIAG' BRACING	9"x4"	12'9"	145	580	A
4	SWAY BRACES	9"x4"	21'6"	240	960	A
4	WALING PIECES	9"x4"	7'0"	80	320	A
2	WALING PIECES	9"x4"	3'3"	35	70	A
4	BOLTS, NUTS & WASHERS	5/8"	20"	2	8	B
30	DRIFT BOLTS	5/8"	15"	1½	45	
20	DOGS	3/8"	9"	1	20	
40	SPIKES		8"	½	20	
1	PACKING	12"x12"	12'	540	540	A.C.
4	PACKING	9"x9"	9"	20	80	A.B.
3	PACKING	4"x1½"	12'	10	30	A.C.
2	PACKING	6"x6"	12'	135	270	A.C.
8	CHOCKS	9"x4"	12"	10	80	A.D.
		TOTAL 13233 lb = 5·97 TONS				

A GROUP I TIMBER AT 45 LB PER CUB FT
B FOR JOINING BRACES WHERE THEY CROSS
C TO LEVEL THE JUNCTION OF THE TWO SPANS
D TO KEEP RAKERS IN POSITION

TIMBER JOINTS.

FIG. 1. Plain Butt Joint with Fish Plates

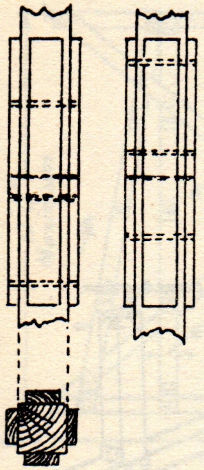


FIG. 2. Oblique Scarf

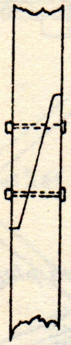


FIG. 3. Table Scarf

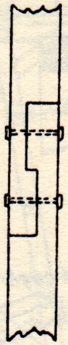


FIG. 4. Half Lap

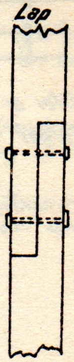


FIG. 5. Housing

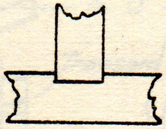
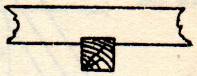
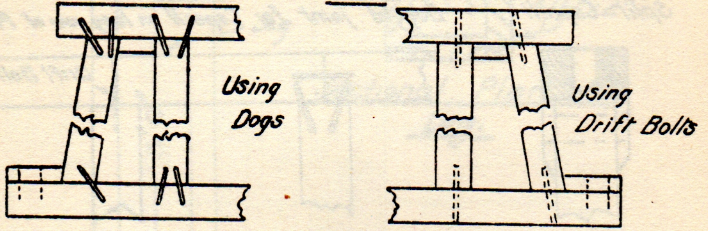


FIG. 6. Single Notch

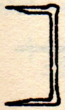


TRESTLE JOINTS.

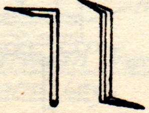
FIG. 7.


Using Dogs
Using Drift Bolts

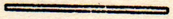
Square Dog



Skew Dog



Drift Bolt



Plain round iron bar.
20" long for 12"×12" Timbers

TIMBER JOINTS.

FIG. 1.

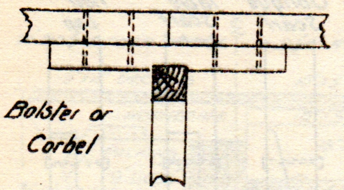

Bolster or
Corbel

FIG. 2.

Wrought iron plate in Trestle construction.

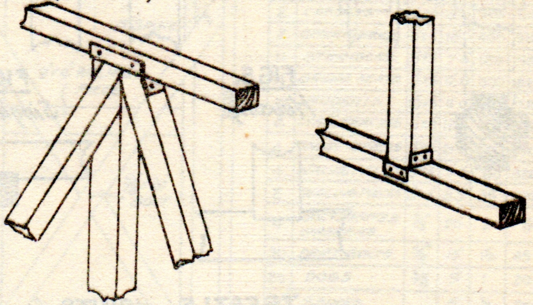


FIG. 3.

Split Capsill

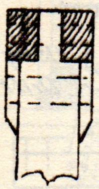


FIG. 4.

Dogged joint for Capsill on long row of Piles

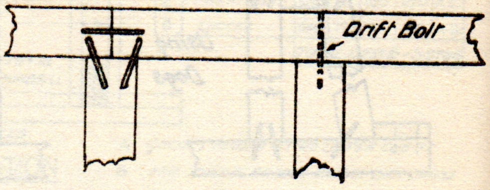
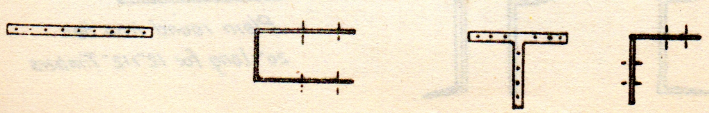


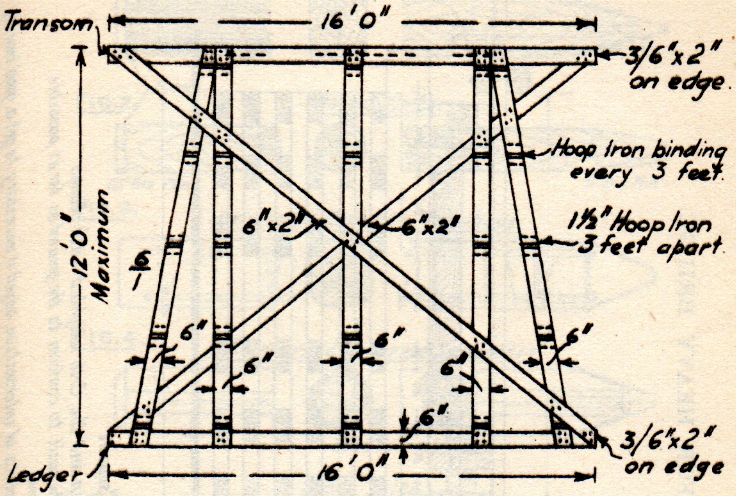
FIG. 5.

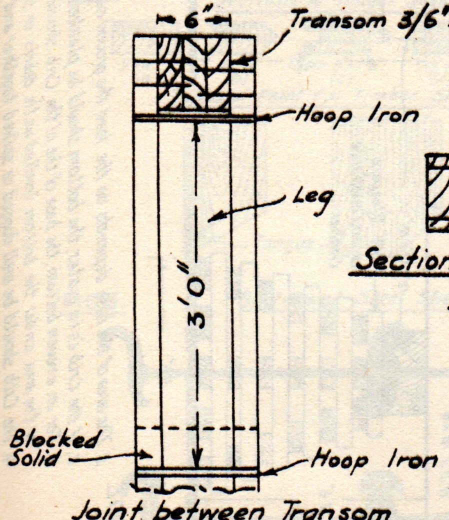
Straps



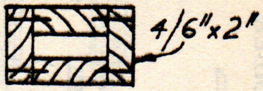
PLANK TRESTLES.

OUT OF 6″ × 2″ TIMBER.


Transom
16′0″
3/6″×2″ on edge
Hoop Iron binding every 3 feet.
6″×2″
6″×2″
1½″ Hoop Iron 3 feet apart
12′0″ Maximum
6/1
6″
6″
6″
6″
6″
6″
Ledger
16′0″
3/6″×2″ on edge

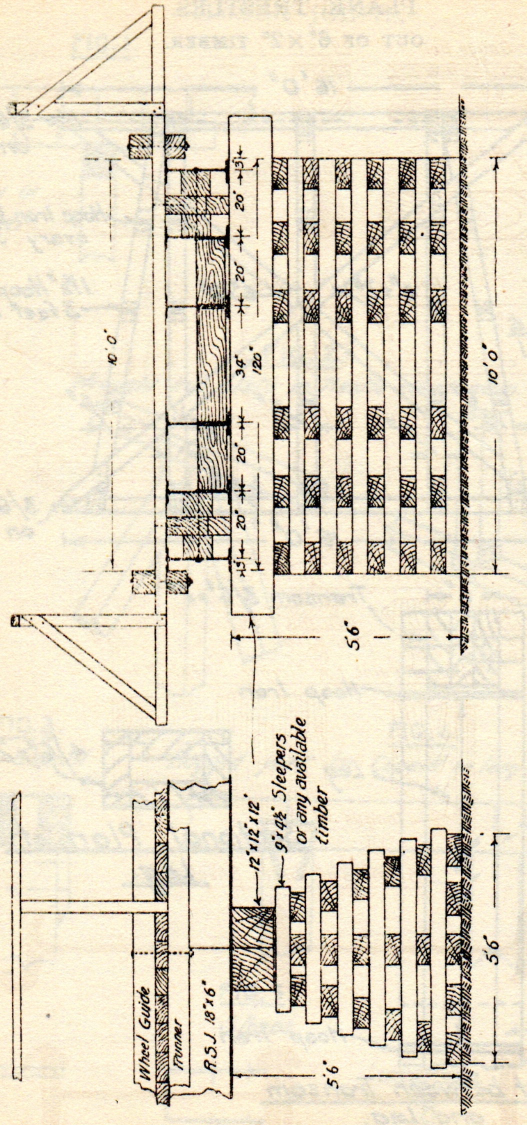

6″
Transom 3/6″×2″
Hoop Iron
Leg
3′0″
Blocked Solid
Hoop Iron

Joint between Transom and Leg.



Sectional Plan of Leg.

TIMBER CRIB PIER FOR HEAVY BRIDGE.

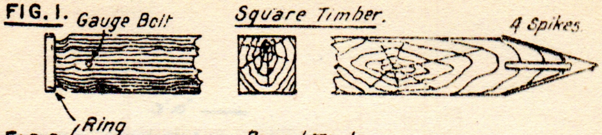

10'0"
20"
3½"
34"
120"
5'6"
10'0"
12"x12"x12'
9"x4½" Sleepers or any available timber
Wheel Guide
Runner
R.S.J. 18"x6"
5'6"
5'6"

NOTE.
1. The area of the base depends on the load the ground can support
2. If the Crib is in water, the bottom should be planked in and the Crib weighted with stones
3. For an uneven bottom, the base of the of the Crib should be built to conform to the ground as far as possible, or the area under the bottom levelled with debris or stones.
4. The Crib should be well dogged or spiked together and points of intersection adzed if necessary to get a good bearing

---

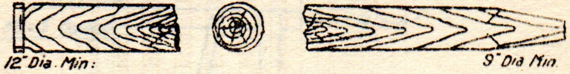
PILES.

FIG. 1.


Gauge Bolt
4 Spikes.
Ring

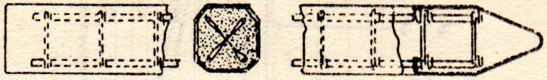
Square Timber.

FIG. 2.


12" Dia. Min.
9" Dia. Min.

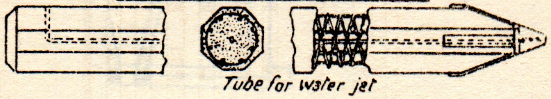
Round Timber.

FIG. 3.



Reinforced Concrete Hennibque.

FIG. 4.

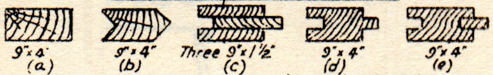

Tube for water jet

Reinforced Concrete Considère.

FIG. 5.

Sheet Piles

Sections of Timber Sheet Piles


9"x4"
(a)
9"x4"
(b)
Three 9"x1½"
(c)
9"x4"
(d)
9"x4"
(e)

Types of Point for Timber Sheet Piles

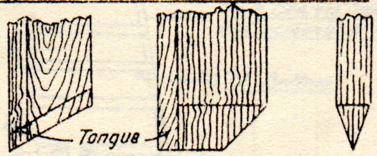
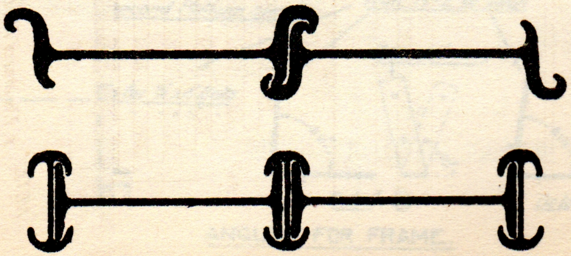


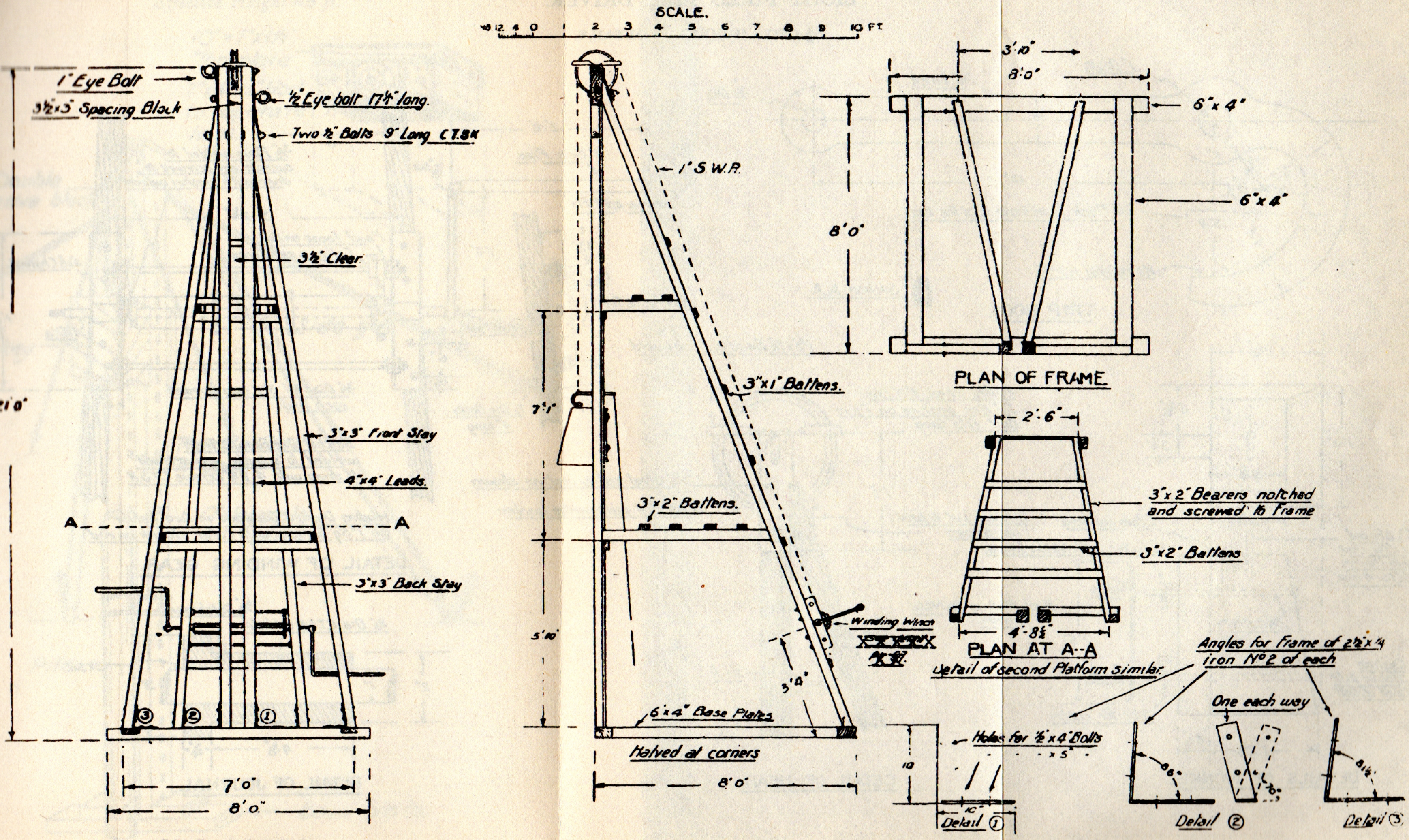
FIG. 6.

Sections of Steel Sheet Piles.



LIGHT FIELD PILE DRIVER.

$8\frac{3}{4}$-CWT. MONKEY.



FRONT ELEVATION

SIDE ELEVATION

PLAN OF FRAME

PLAN AT A-A

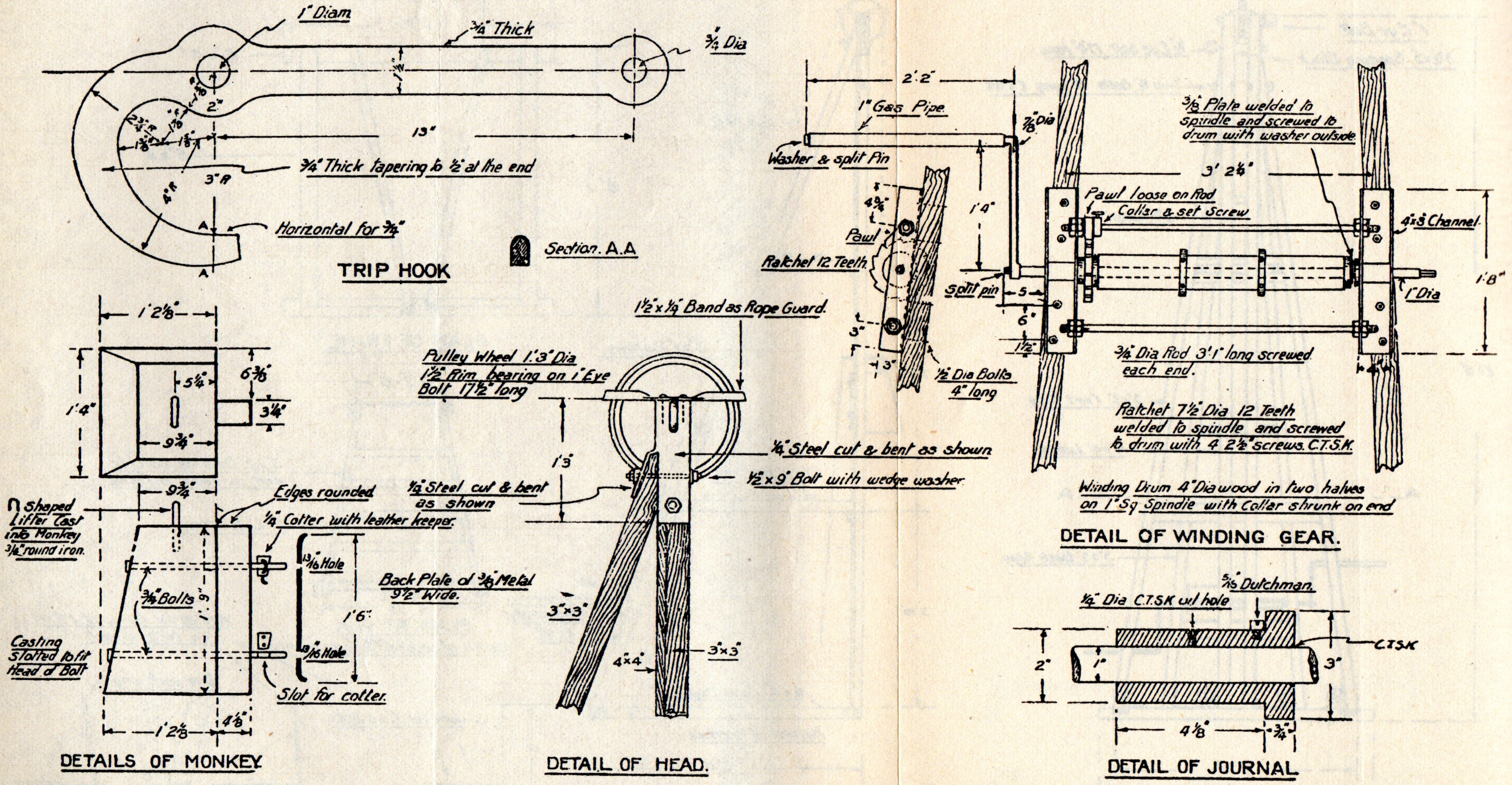
Detail of second Platform similar.

ANGLES FOR FRAME.

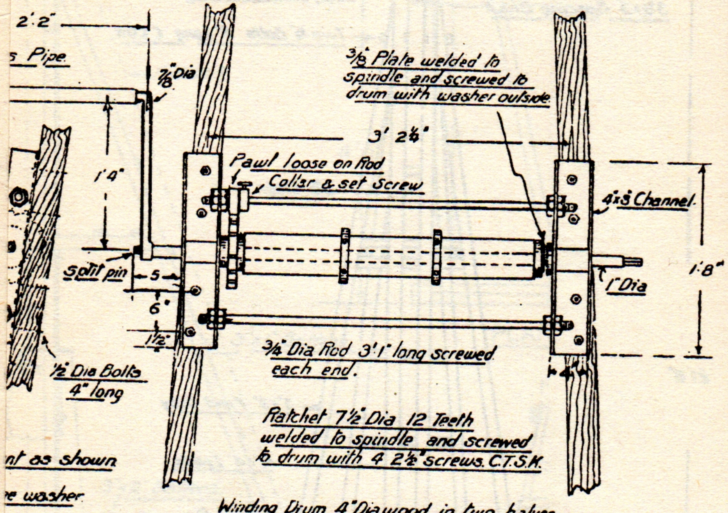
SCALE.
12 6 0 1 2 3 4 5 6 7 8 9 10 FT.
1" Eye Bolt
3½"x3" Spacing Block
½" Eye bolt 17¼" long.
Two ½" Bolts 9" long C.T.&K.
3½" Clear
3"x3" Front Stay
4"x4" Leads.
A
A
3"x3" Back Stay
21'0"
③
②
①
7'0"
8'0"
1" S.W.R.
3"x1" Battens.
7'1"
3"x2" Battens.
5'10"
Winding Winch
Pk 27.
3'4"
6"x4" Base Plates
Halved at corners
8'0"
3'10"
8'0"
6"x4"
6"x4"
8'0"
2'6"
3"x2" Bearers notched and screwed to frame
3"x2" Battens
4'-8½"
Angles for Frame of 2½"x¼" iron No 2 of each
One each way
Holes for ½"x4" Bolts
x 5"
10
10"
6"
6"
8½"
Detail ①
Detail ②
Detail ③

LIGHT FIELD PILE DRIVER.

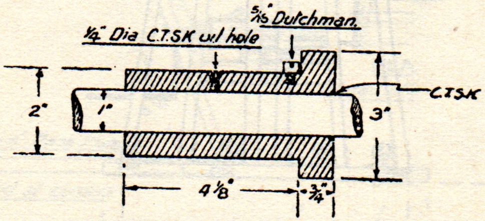
8¾-CWT. MONKEY. DETAILS.


1" Diam
3/4" Thick
3/4 Dia
1 1/4"
2"
13"
3/4" Thick tapering to 1/2 at the end
3" R
4" R
2 3/4" R
A
Horizontal for 3/4"
Section. A.A
TRIP HOOK
1' 2 7/8"
1' 4"
5 1/4"
6 3/8"
3 1/4"
9 3/4"
9 3/4"
∩ Shaped Lifter Cast into Monkey 3/4" round iron.
Edges rounded
1/4" Cotter with leather keeper.
13/16 Hole
13/16 Hole
3/4 Bolts
1' 9"
1' 6"
Back Plate of 3/8 Metal 9 1/2" Wide.
Casting Slotted to fit Head of Bolt
Slot for cotter.
1' 2 7/8"
4 1/8"
DETAILS OF MONKEY
Pulley Wheel 1' 3" Dia
1 1/2" Rim bearing on 1" Eye Bolt 17 1/2" long
1 1/2" x 1/4" Band as Rope Guard.
1' 3"
1/4" Steel cut & bent as shown
1/2" x 9" Bolt with wedge washer.
1/8 Steel cut & bent as shown
3" x 3"
4" x 4"
3" x 3"
DETAIL OF HEAD.
2' 2"
1" Gas Pipe.
7/8 Dia
Washer & split Pin
1' 4"
4 3/4"
Pawl
Ratchet 12 Teeth.
Split pin
5
6"
3"
1 1/2"
3"
1/2 Dia Bolts 4" long
3/8 Plate welded to spindle and screwed to drum with washer outside.
3' 2 1/4"
Pawl loose on Rod
Collar & set Screw
4" x 3" Channel.
1' 8"
1" Dia
3/4" Dia Rod 3' 1" long screwed each end.
Ratchet 7 1/2" Dia 12 Teeth welded to spindle and screwed to drum with 4 2 1/2" screws. C.T.S.K.
Winding Drum 4" Dia wood in two halves on 1" Sq Spindle with Collar shrunk on end
DETAIL OF WINDING GEAR.
5/16 Dutchman.
1/4" Dia C.T.S.K. oil hole
C.T.S.K.
2"
1"
3"
4 1/8"
3/4"
DETAIL OF JOURNAL.

R.


2'.2"
s Pipe
7/8" Dia
1'4"
Split pin
5
6"
1½"
½" Dia Bolts 4" long
nt as shown
e washer
3/8" Plate welded to spindle and screwed to drum with washer outside.
3' 2¼"
Pawl loose on Rod
Collar & set Screw
4x3 Channel.
1'8"
1" Dia
¾" Dia Rod 3'1" long screwed each end.
Ratchet 7½" Dia 12 Teeth welded to spindle and screwed to drum with 4 2½" screws. C.T.S.K.
Winding Drum 4" Dia wood in two halves on 1" Sq Spindle with Collar shrunk on end

DETAIL OF WINDING GEAR.

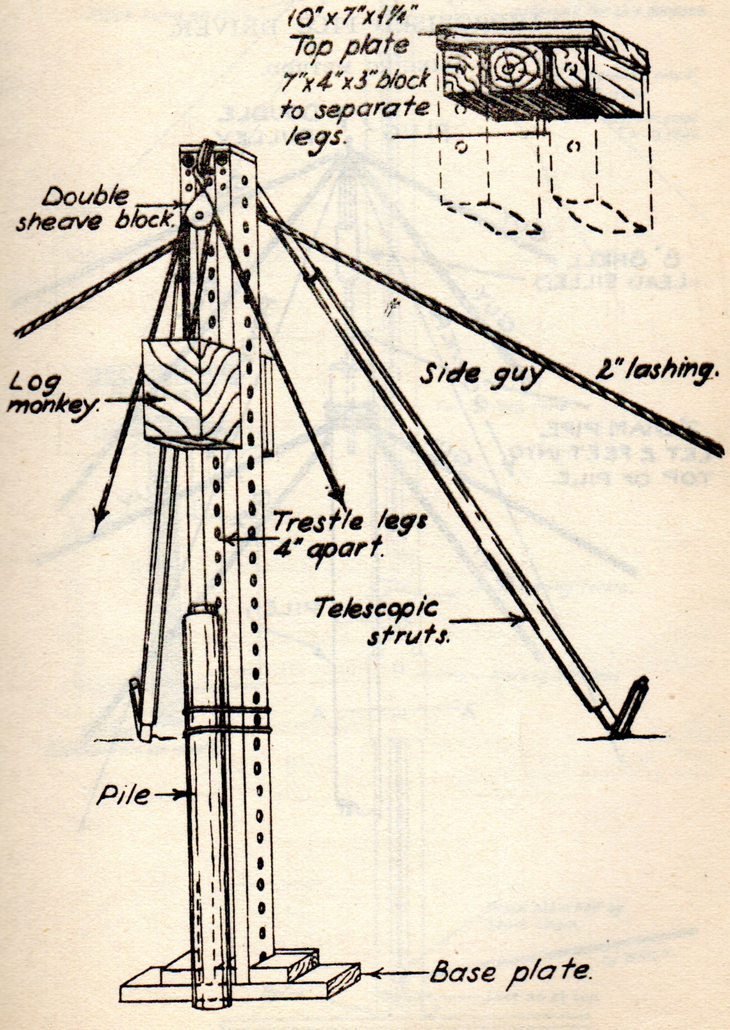

5/16" Dutchman.
¼" Dia C.T.S.K oil hole
2"
1"
3"
C.T.S.K
4⅛"
¾"

DETAIL OF JOURNAL

LIGHT PILE DRIVER.

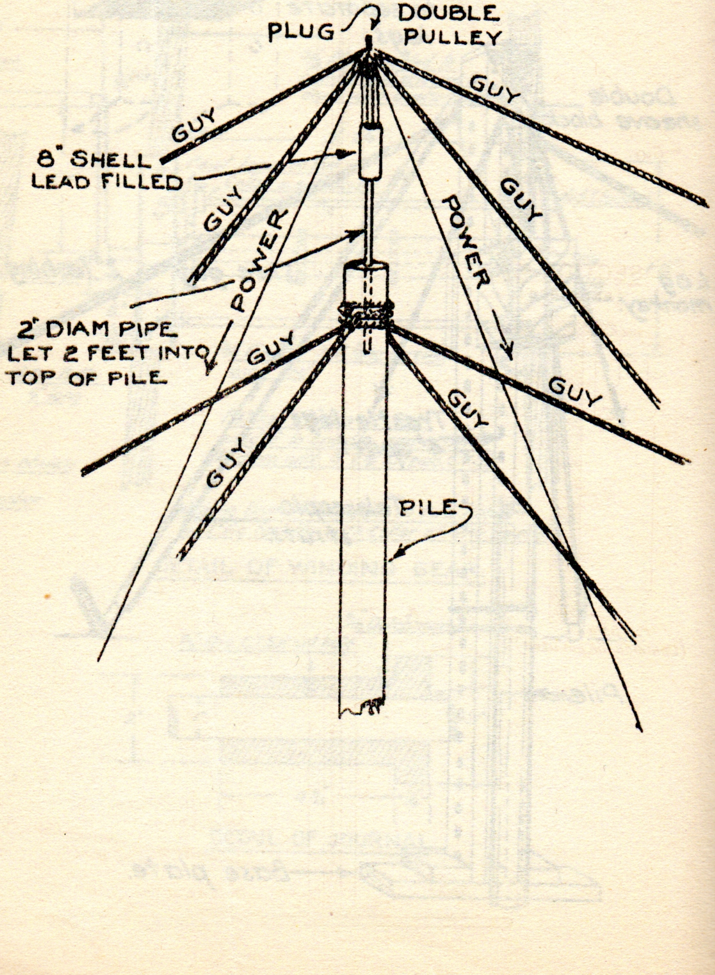
IMPROVISED FROM TRESTLE LEGS.

Effective Height = 5 ft.

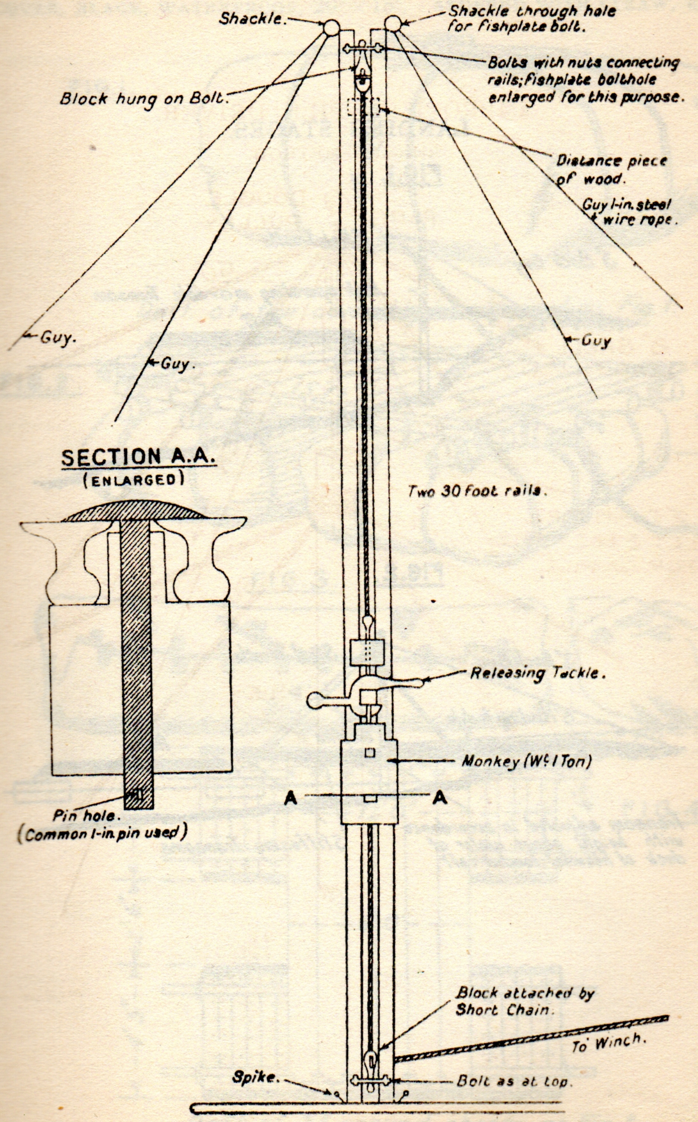

10" x 7" x 1¼" Top plate
7" x 4" x 3" block to separate legs.
Double sheave block.
Log monkey.
Side guy
2" lashing.
Trestle legs 4" apart.
Telescopic struts.
Pile
Base plate.

IMPROVISED PILE DRIVER.

RINGING METHOD.


PLUG
DOUBLE PULLEY
GUY
GUY
8" SHELL LEAD FILLED
GUY
GUY
POWER
POWER
2" DIAM PIPE LET 2 FEET INTO TOP OF PILE
GUY
GUY
GUY
GUY
PILE

PILE-DRIVER IMPROVISED FROM STEEL RAILS.


Shackle.
Shackle through hole for fishplate bolt.
Bolts with nuts connecting rails; fishplate bolthole enlarged for this purpose.
Block hung on Bolt.
Distance piece of wood.
Guy 1-in. steel wire rope.
Guy.
Guy.
Guy
SECTION A.A.
(ENLARGED)
Pin hole.
(Common 1-in. pin used)
Two 30 foot rails.
Releasing Tackle.
Monkey (Wt 1 Ton)
A
A
Block attached by Short Chain.
To Winch.
Spike.
Bolt as at top.

LANDING STAGES.

FIG. 1.

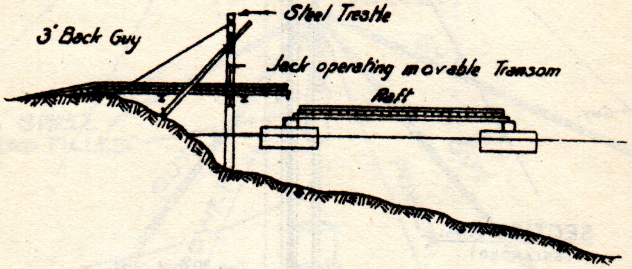
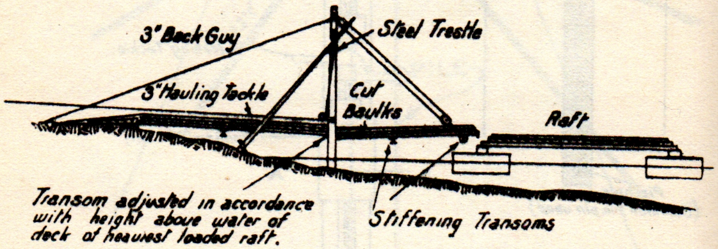

Steel Trestle
3' Back Guy
Jack operating movable Transom
Raft

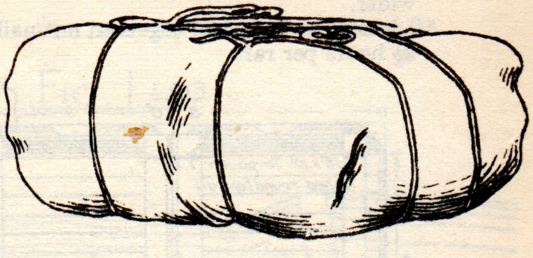
FIG. 2.


3" Back Guy
Steel Trestle
3" Hauling Tackle
Cut Baulks
Raft
Transom adjusted in accordance with height above water of deck of heaviest loaded raft.
Stiffening Transoms

BRIDGING EXPEDIENTS.

COVER, BLACK, WATERPROOF, 20′ × 15′. STUFFED WITH STRAW, ETC.

FIG. 1.



Raft of four covers, black, waterproof as Fig. 1.

FIG. 2.

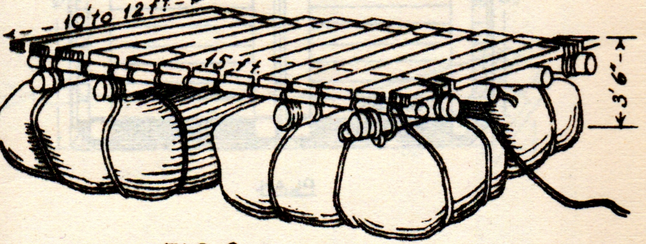

10' to 12 ft.
15 ft.
3' 6"

FIG. 3.

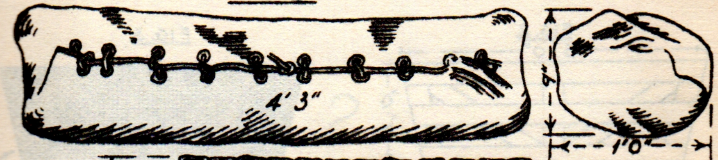
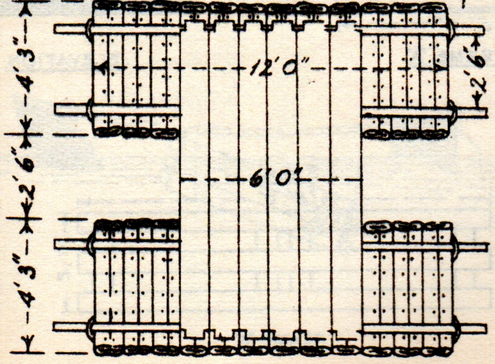


FIG 4.


4' 3"
2' 6"
12' 0"
2' 6"
6' 0"
4' 3"

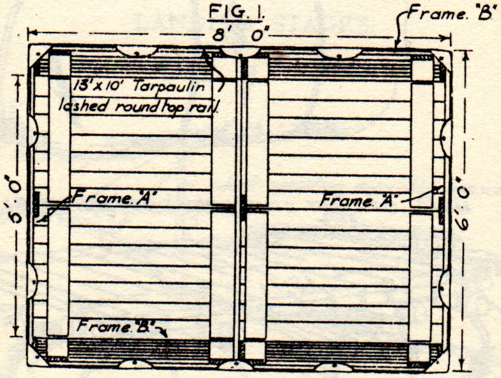
Raft of 24 ground sheets as Fig. 3.

BIVOUAC SHEET BOAT.

Note :—Framing about 5″ × ¾″. Bottom same form as " B " but wider.

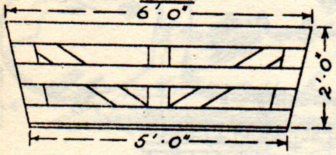
All frames to be lashed together, not nailed. 4 carpenters 2½ hours per raft.

FIG. 1.


Frame. 'B'
8' 0"
13'x10' Tarpaulin
lashed round top rail.
Frame. 'A'
Frame. 'A'
5' 0"
6' 0"
Frame. 'B'

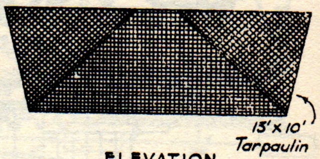
PLAN.

FIG. 2.



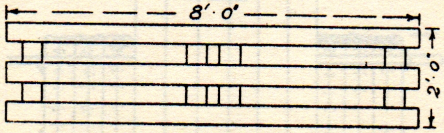
FRAME. 'A'.

FIG. 3.


13'x10'
Tarpaulin

ELEVATION.

FIG. 4.



FRAME. 'B'.

FLYING BRIDGES.

FIG. 1.

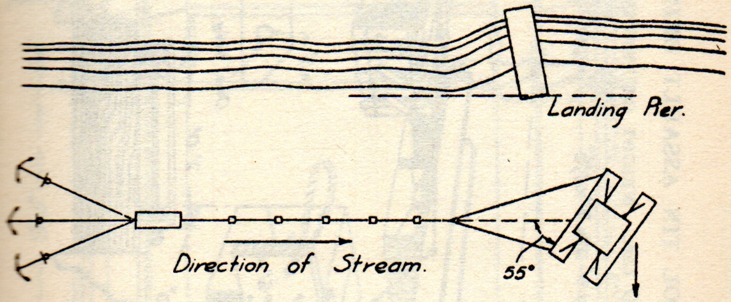
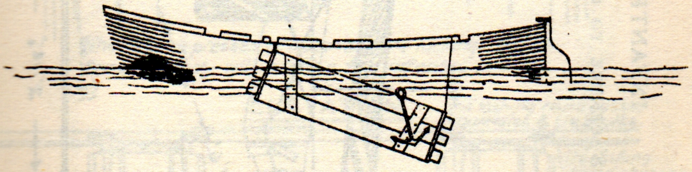
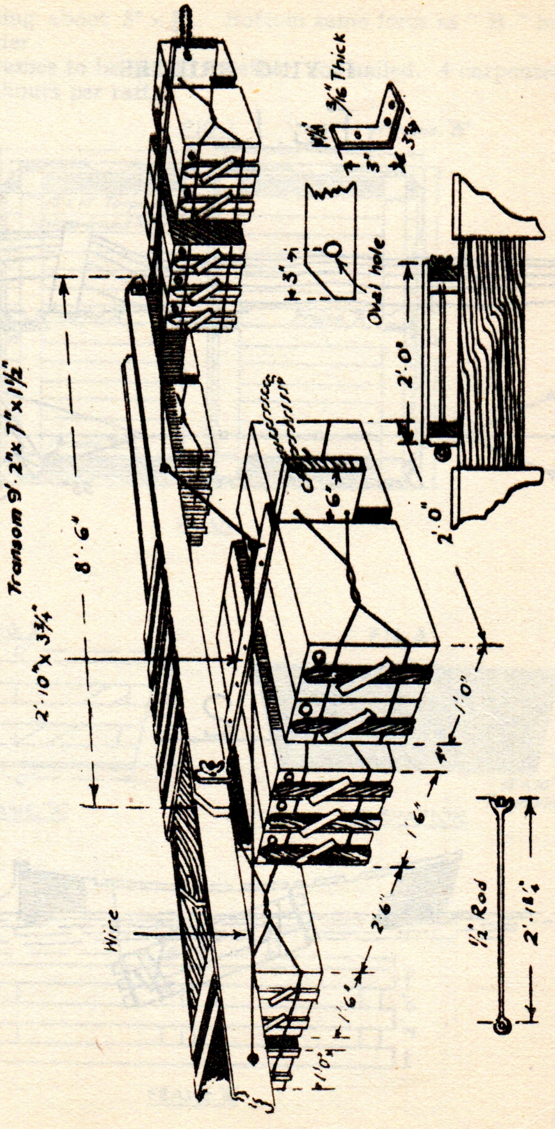

Landing Pier.
Direction of Stream.
55°

FIG. 2.



INFANTRY FOOT-BRIDGE. PETROL TIN ASSAULT BRIDGE.

PIERS 8' CENTRE TO CENTRE. WEIGHT OF PIER 110 LBS. WEIGHT OF TRENCH BOARD 48 LBS.

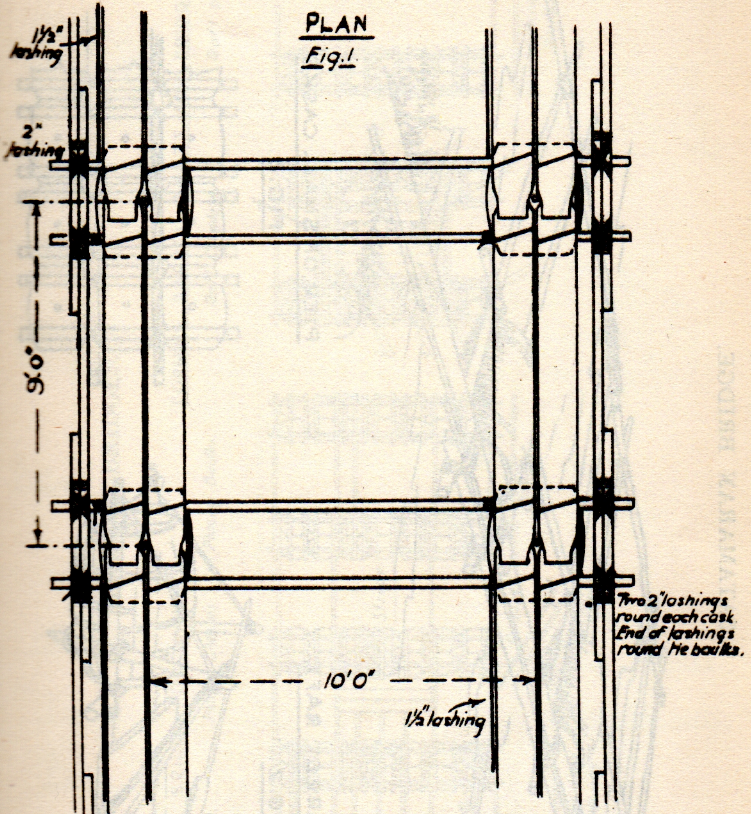

Transom 9'.2" x 7" x 1½"
2'.10" x 3¾"
8'.6"
3/16" Thick
3"
3¾"
3"
Oval hole
2'.0"
6"
2'.0"
1'.0"
4"
1'.6"
2'.6"
1'.6"
1'.0¼"
Wire
½" Rod
2'.1¾"

INFANTRY FOOT-BRIDGE. CASK FOOT-BRIDGE.

FOR 54 GALLON CASKS.

PLAN

Fig. 1.


1½" lashing
2" lashing
9'.0"
Two 2" lashings round each cask. End of lashings round tie baulks.
10'.0"
1½" lashing

Where time presses or materials are lacking, planks one side only will suffice for infantry in file.

ELEVATION.

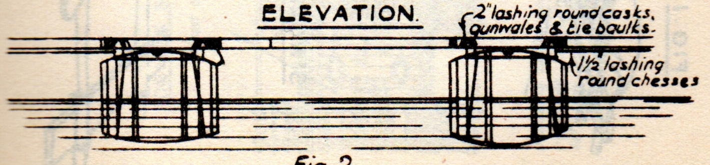
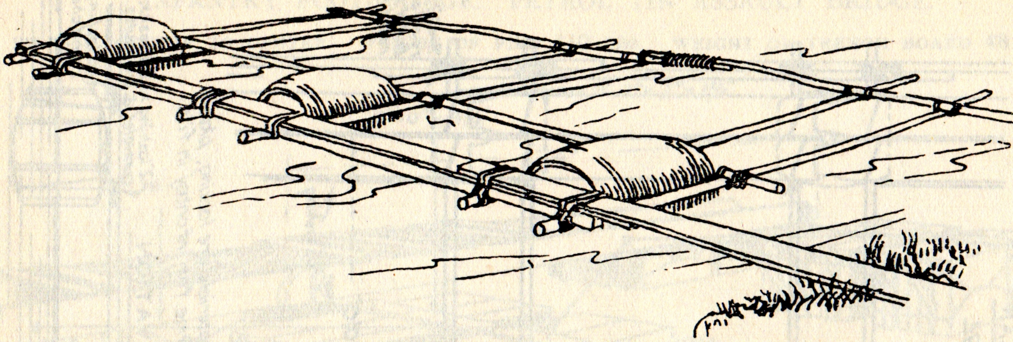

2" lashing round casks, gunwales & tie baulks.
1½ lashing round chesses

Fig. 2.

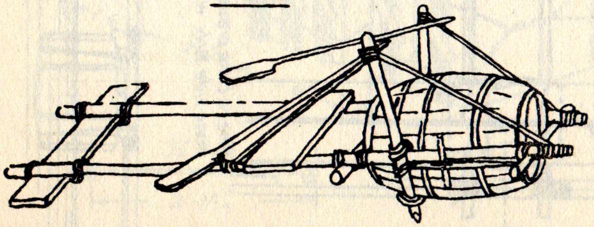
CATAMARAN BRIDGE.

FIG. 1.



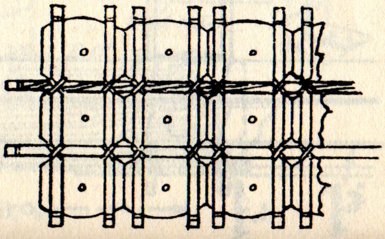
SINGLE BARREL RAFT.

FIG. 2.



PIER OF SMALL CASKS.

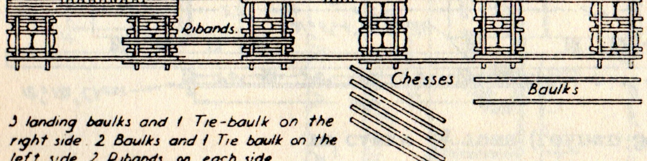
FIG. 3.



BARREL BRIDGES.

FIG. 1

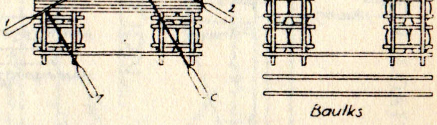
FORMING BARREL BRIDGE FOR SWINGING


Head of Bridge
Placing Chesses
Placing Baulks
1
Deep
Stream
Ribands.
Chesses
Baulks

3 landing baulks and 1 Tie-baulk on the right side. 2 Baulks and 1 Tie baulk on the left side 2 Ribands on each side

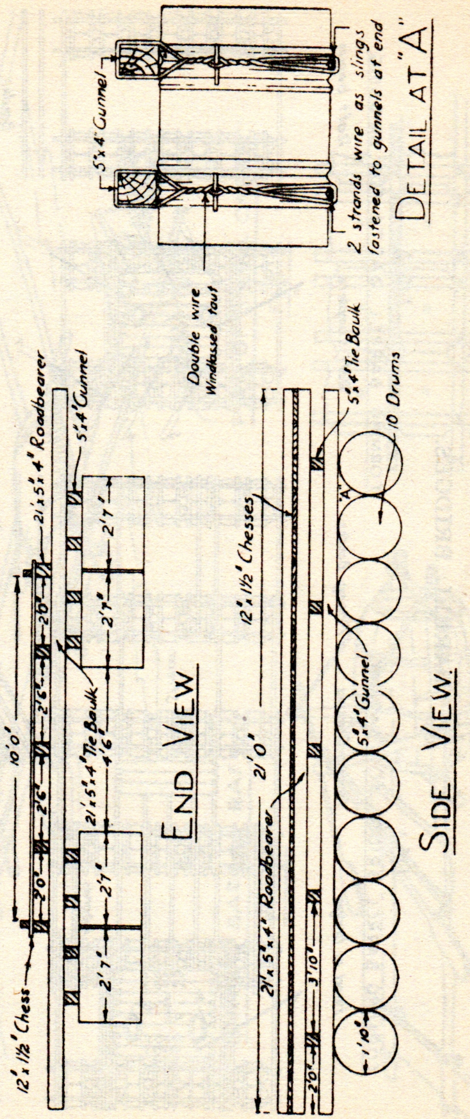
FIG 2.

FORMING BARREL RAFTS FOR BRIDGING


Raft Complete
Raft begun
1
5
3
1
6
4
2
7
c
Baulks

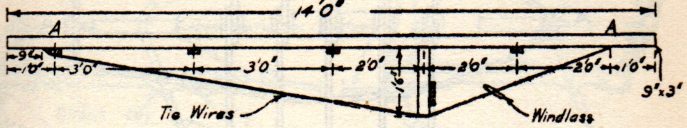
RAFT OF STEEL DRUMS.

TO CARRY 4½ TONS (LOADED 30-CWT. LORRY).


DETAIL AT "A"
5"x4" Gunnel
2 strands wire as slings fastened to gunnels at end
Double wire Windlassed taut
12"x1½" Chess
21'x5"x4" Roadbearer
5"x4" Gunnel
10'0"
2'0"
2'6"
2'6"
2'0"
21'x5"x4" Tie Baulk
4'6"
2'7"
2'7"
2'7"
2'7"
END VIEW
21'0"
12"x1½" Chesses
21'x5"x4" Roadbearer
5"x4" Tie Baulk
10 Drums
"A"
5"x4" Gunnel
3'10"
2'0"
1'10"
SIDE VIEW.

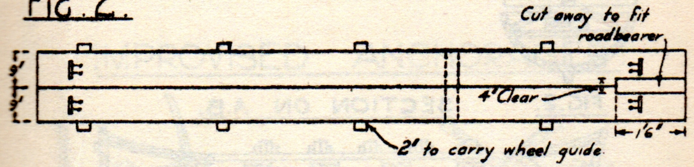
DETAIL OF LOADING RAMP FOR LOADED 30-CWT. LORRY.

FIG. 1.


14'0"
A
A
9"
1'0"
3'0"
3'0"
2'0"
1'6"
2'6"
2'6"
1'0"
9"x3"
Tie Wires
Windlass

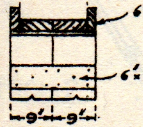
SIDE ELEVATION.

FIG. 2.


Cut away to fit roadbearer
9"
9"
4" Clear
1'6"
2" to carry wheel guide.

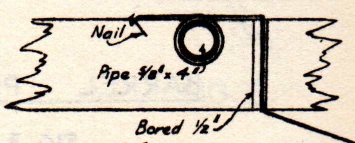
PLAN.

FIG. 3.


1'6"
6"x2"
6"x1"
9"
9"

END ELEVATION.

FIG. 4.

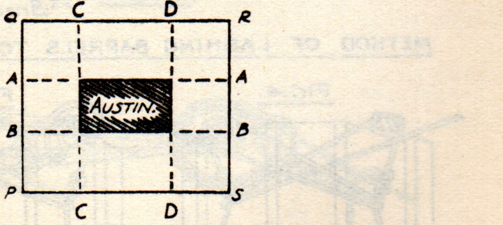

Nail
Pipe ⅜"x 4"
Bored ½"

DETAIL AT 'A' FOR FIXING WIRES.

FLOATING AN AUSTIN 7 IN A TARPAULIN

18' x 15'.

FIG. 5.


Q
C
D
R
A
A
AUSTIN.
B
B
P
C
D
S

BOAT PIER.

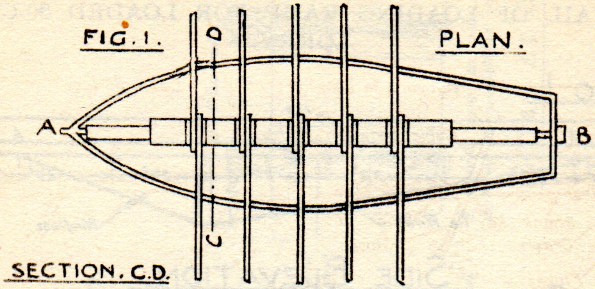


FIG.1. PLAN.

SECTION. C.D.

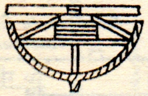
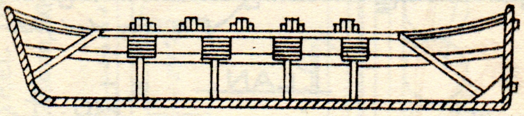
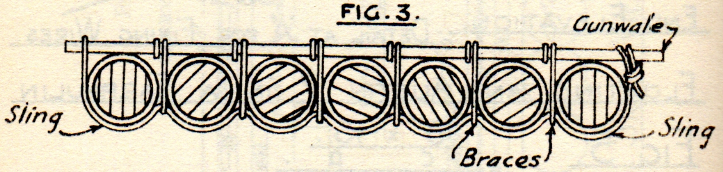


FIG.2. SECTION ON A.B.



BARREL PIER.

FIG.3.


Gunwale
Sling
Sling
Braces

METHOD OF LASHING BARRELS TO GUNWALES.

FIG.4.

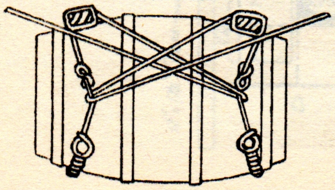
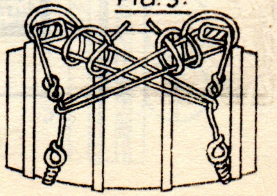


FIG.5.



KEDGE AND ANCHOR FASTENINGS.

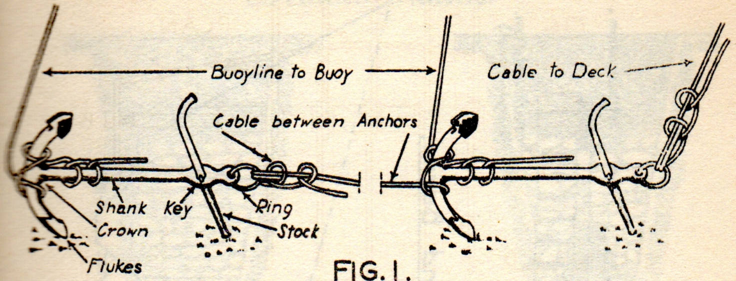

Buoyline to Buoy
Cable to Deck
Cable between Anchors
Shank
Key
Ring
Crown
Stock
Flukes

FIG.1.

IMPROVISED ANCHORAGES.

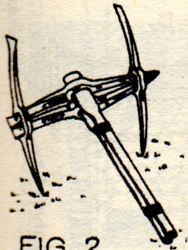


FIG. 2.

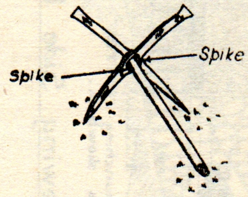

Spike
Spike

FIG. 3.

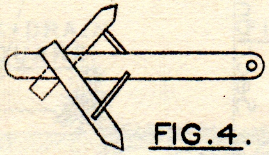


FIG. 4.

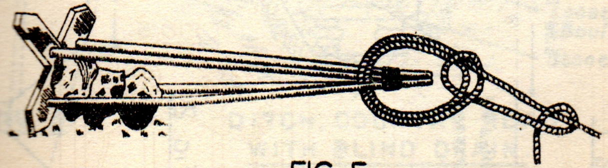


FIG. 5.

SIDE DRAINS.

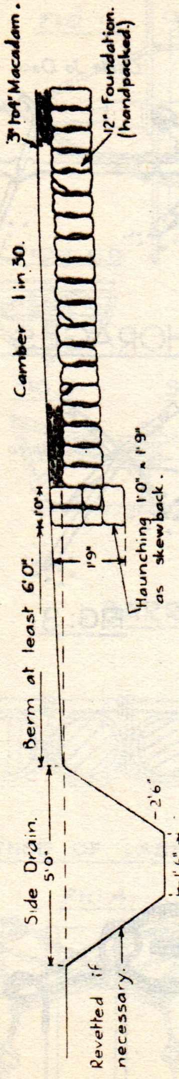

3" to 4" Macadam.
12" Foundation. (handpacked.)
Camber 1 in 30.
Berm at least 6'0".
1'0"
1'9"
Haunching 1'0" x 1'9" as skewback.
Side Drain. 5'0"
2'6"
1'6"
Revetted if necessary

FIG. 1. Cross Section Shewing Side Drain and Berm.

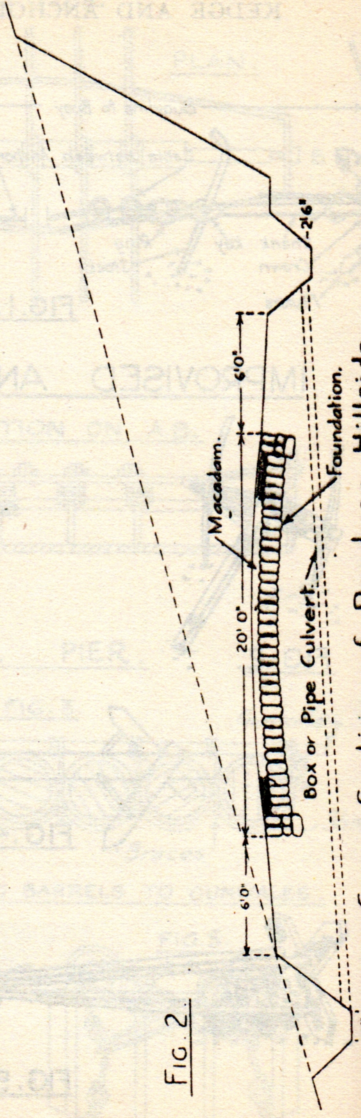

2'6"
6'0"
20'0"
6'0"
Macadam.
Foundation.
Box or Pipe Culvert.
1'6"

FIG. 2. Cross Section of Road on Hillside.

COVERED DRAINS.

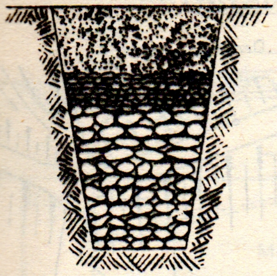


FIG. 1. BLIND DRAIN.

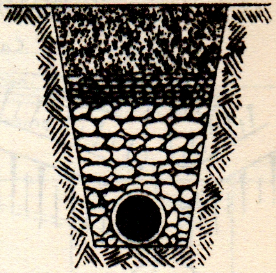


FIG. 2. TILE DRAIN.

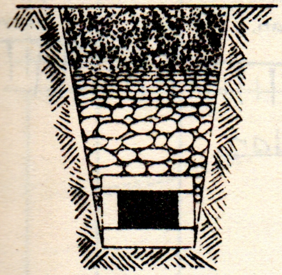


FIG. 3. BOX-DRAIN SQUARE.

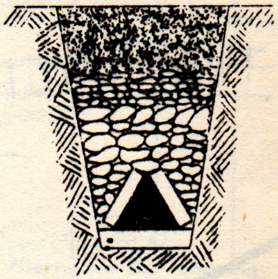


FIG. 4. BOX-DRAIN TRIANGULAR.

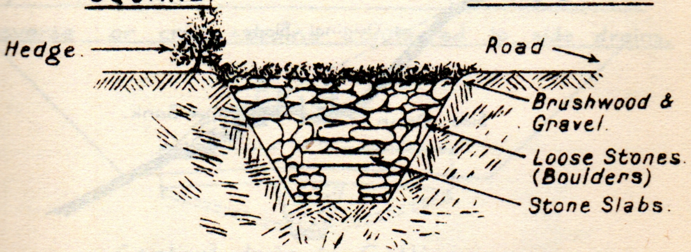

Hedge.
Road
Brushwood & Gravel.
Loose Stones. (Boulders)
Stone Slabs.

FIG. 5. DITCH, COUNTRY ROAD WITH BLIND DRAIN.

CATCH-WATER DRAINAGE.

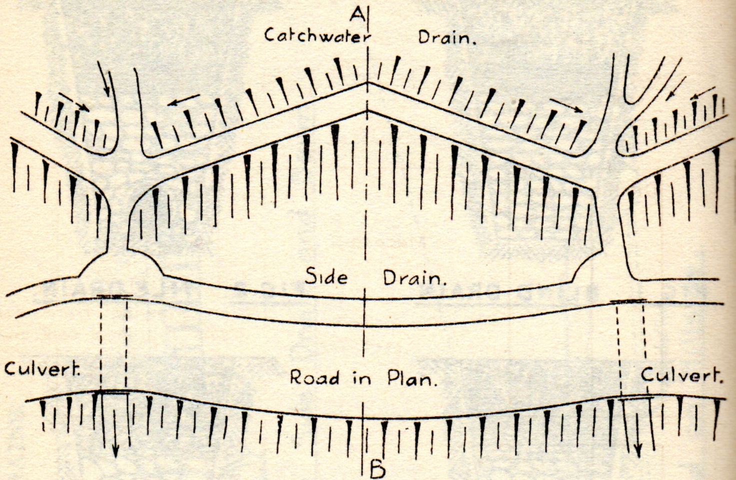

A
Catchwater Drain.
Side Drain.
Culvert.
Road in Plan.
Culvert.
B

Fig.1. Plan.

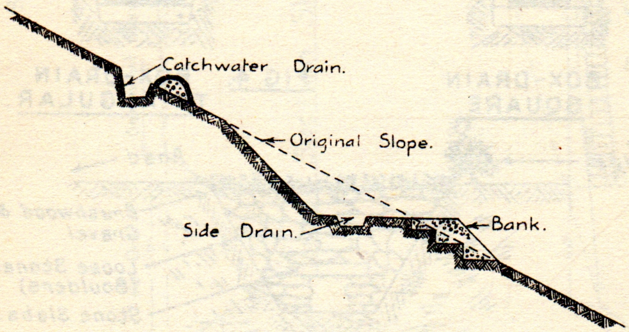

Catchwater Drain.
Original Slope.
Side Drain.
Bank.

Fig.2. Section on-A.B.

DRAINAGE OF FORMATION.

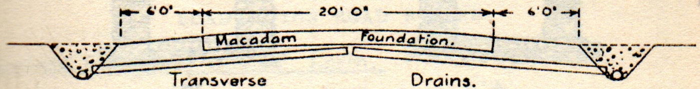

6'0"
20' 0"
6'0"
Macadam
Foundation.
Transverse
Drains.

Fig.1.

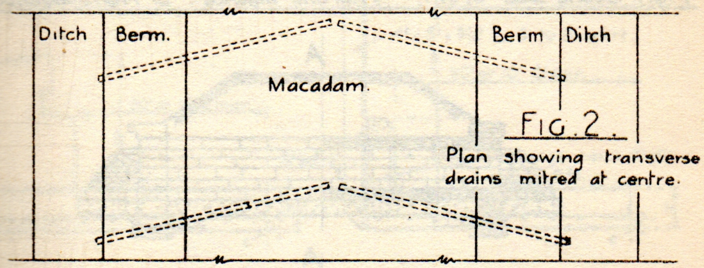

Ditch
Berm.
Macadam.
Berm
Ditch

Fig.2.

Plan showing transverse drains mitred at centre.

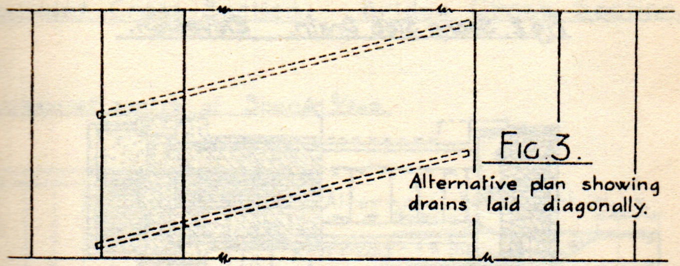


Fig.3.

Alternative plan showing drains laid diagonally.

Transverse or cross-drains connected to side drains.

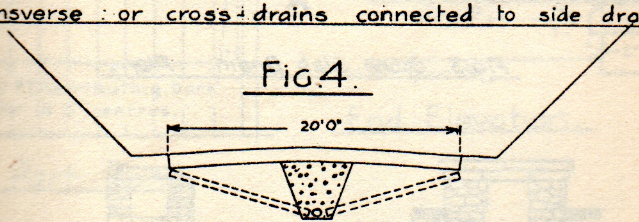


Fig.4.

Central drain in Cutting.

SLAB DRAINS.

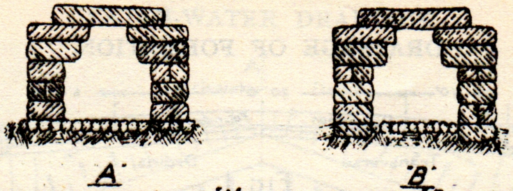


Fig. 1. Stone slab drain. "A" wrong method. "B" right method.

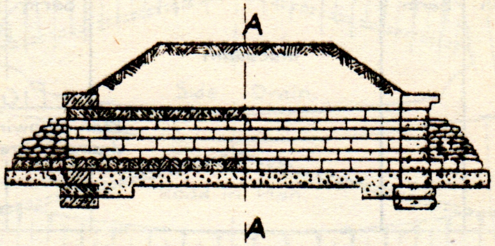


Fig. 2. Stone Slab Drain. Elevation.

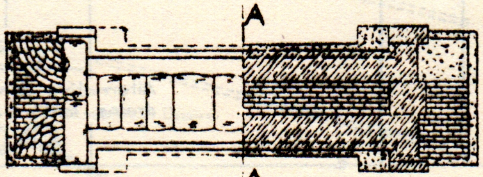


Fig. 3. Stone Slab Drain. Plan.

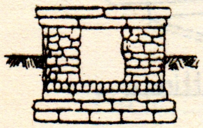


Fig. 4 End Elevation.

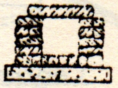


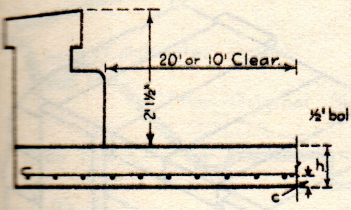
Fig. 5. Section A.A.

REINFORCED-CONCRETE SLAB SPANS.

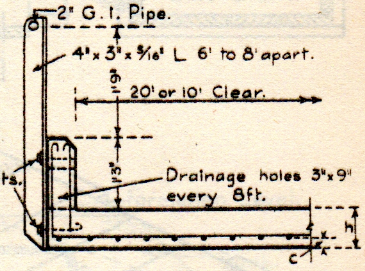
LOAD 12-TON ROAD ROLLER.

Surface 6' Metal on 1½' Earth.

P.C. Concrete 90lbs: 2: 4.

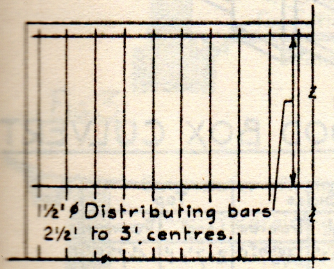

20' or 10' Clear.
2' 1½"
h
c
c

Culvert Cross Section.

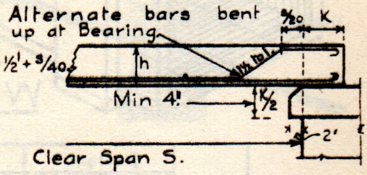

2" G. I. Pipe.
4" x 3" x 5/16" L 6' to 8' apart.
9"
20' or 10' Clear.
½" bolts.
1' 3"
Drainage holes 3" x 9" every 8ft.
h
c

Bridge Cross Section.

Camber at centre of Span = S/240.

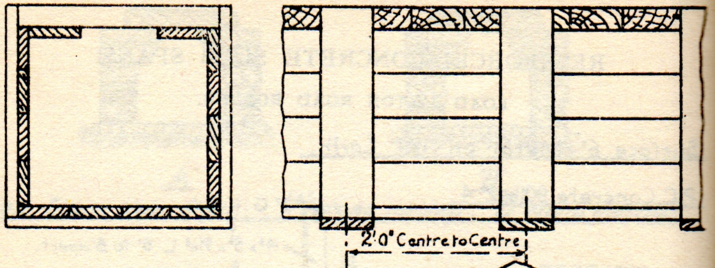

1½' φ Distributing bars 2½' to 3' centres.

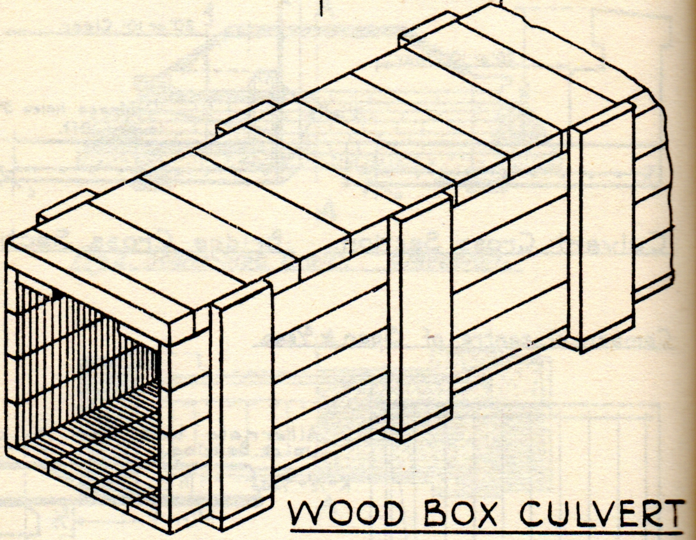
Part Plan.


Alternate bars bent up at Bearing
S/20
K
K = ½' + S/40
h
Min 4'
K/2
2'
Clear Span S.

End Elevation.

For thickness and reinforcement see M.E. Vol V.


2'0" Centre to Centre



WOOD BOX CULVERT

	Bottom		Sides		Top	
	Longl.	Transverse	Longl.	Transverse	Longl.	Transverse
12"×12"	2-7"×1"	16"×7"×1"	2·6"×1"	14½"×7"×1"	2·7"×1"	14"×7"×1½"
18"×18"	2·7"×1" 1 6"×1"	22"×7"×1"	3 6"×1"	21"×7"×1"	2·7"×1"	20"×7"×2"
24"×24"	3·7"×1½" 1·6"×1½"	30"×7"×1½"	4·6"×1½	28½"×7"×1½"	2·7"×1½"	27"×7"×3"
30"×30"	4·7"×2" 1·6"×2"	38"×7"×2"	5·6"×2"	35"×7"×2"	2·7"×2"	34"×7"×3"
36"×36"	6·7"×3"	48"×7"×3"	6·6"×3"	43"×7"×3"	2·7"×3"	42"×7"×4"

SIDELONG SLOPES.

FIG. 1.

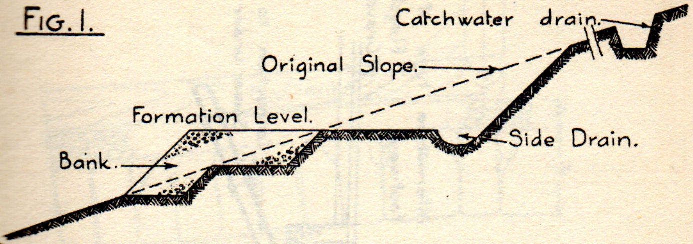

Catchwater drain.
Original Slope.
Formation Level.
Side Drain.
Bank.

FIG. 2.

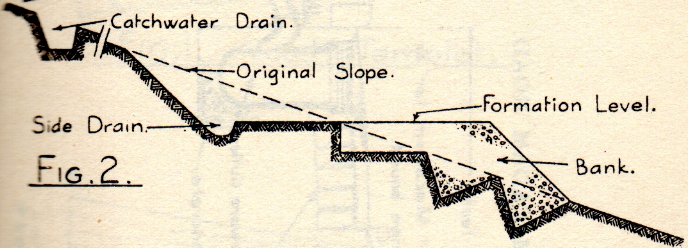

Catchwater Drain.
Original Slope.
Formation Level.
Side Drain.
Bank.

FIG. 3.

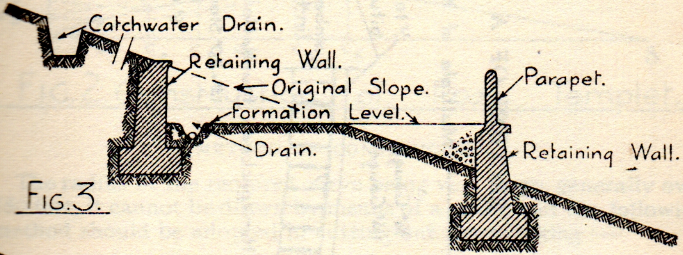
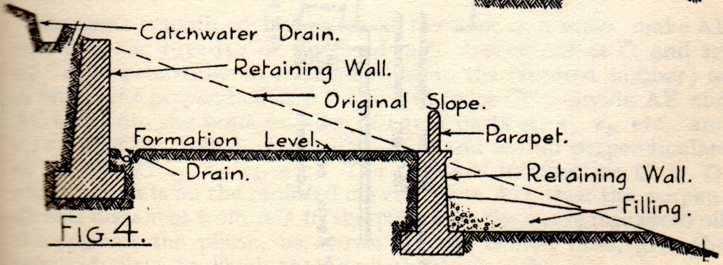
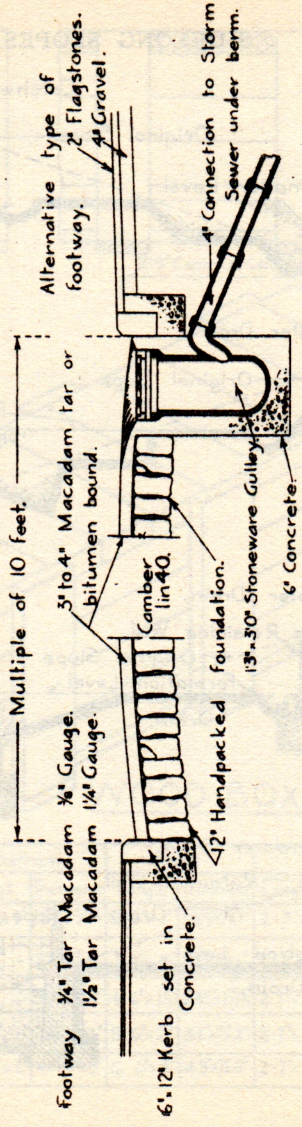

Catchwater Drain.
Retaining Wall.
Original Slope.
Parapet.
Formation Level.
Drain.
Retaining Wall.

FIG. 4.


Catchwater Drain.
Retaining Wall.
Original Slope.
Parapet.
Formation Level.
Drain.
Retaining Wall.
Filling.

SECTION OF A MACADAM ROAD.


Alternative type of footway.
2" Flagstones.
4" Gravel.
4" Connection to Storm Sewer under berm.
Multiple of 10 feet.
3" to 4" Macadam tar or bitumen bound.
Camber 1 in 40.
12" Handpacked foundation.
13"×30" Stoneware Gulley.
6" Concrete.
Footway
¾" Tar Macadam ⅜" Gauge.
1½" Tar Macadam 1¼" Gauge.
6"×12" Kerb set in Concrete.

ROAD TEMPLET.

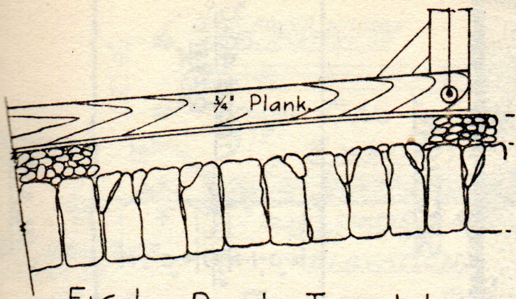


FIG. 1. Road Templet.

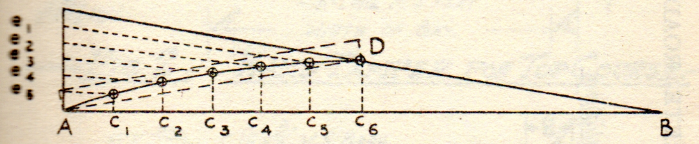

E
e1
e2
e3
e4
e5
D
A
C1
C2
C3
C4
C5
C6
B

FIG. 2. Construction of Road Templet.

METHOD OF CONSTRUCTION.

The radius of the required curve being very large, generally over 150 feet, it cannot be drawn by means of a string and the following method should be adopted in cutting out the planking :—

On some smooth surface, such as the floor of a room, make AB equal to the breadth of the roadway ; bisect AB at C, and set up CD perpendicular to AB and equal to the required camber ; at A set up the perpendicular AE equal to twice CD ; divide AE and AC each into the same number of equal parts e_1, e_2, e_3, etc., and c_1, c_2, c_3, etc. Join e_1, e_2, e_3, etc., to B and set up perpendiculars at the points c_1, c_2, c_3, etc. The points of intersection O, O, O, etc., are points on the required curve. Join AD, then the perpendicular distances from AD to the points on the curve measured off the edge of the plank, as shown by the dotted lines, give the required curve to which the plank should be cut.

CONCRETE ROAD JOINTS.

FIG. 1.

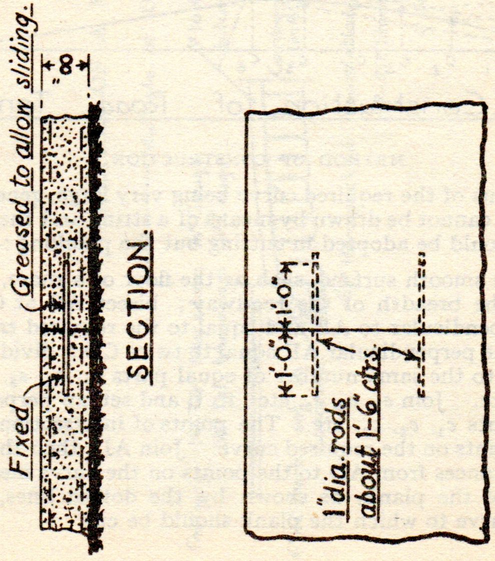
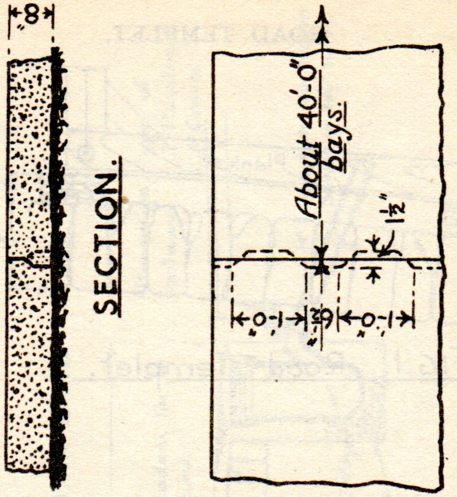

Fixed.
Greased to allow sliding.
8"
SECTION.
PLAN.
1'-0"
1'-0"
1" dia. rods about 1'-6" ctrs.

FIG. 2.


8"
SECTION.
PLAN.
About 40'-0" bays.
1½"
0'-1"
9"
0'-1"

TOOLS FOR CONCRETE ROAD CONSTRUCTION.

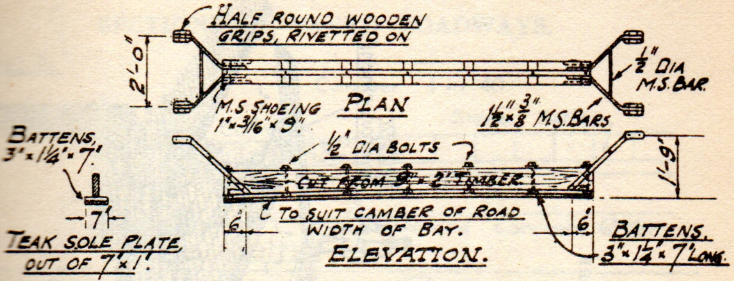

HALF ROUND WOODEN GRIPS, RIVETTED ON
2'-0"
½" DIA M.S. BAR.
M.S. SHOEING 1"×3/16"×9".
PLAN
1½"×⅜" M.S. BARS
BATTENS, 3"×1¼"×7'.
½" DIA BOLTS
CUT FROM 9"×2" TIMBER
1'-9"
TO SUIT CAMBER OF ROAD
WIDTH OF BAY.
6
6
7
TEAK SOLE PLATE OUT OF 7"×1".
ELEVATION.
BATTENS. 3"×1¼"×7' LONG.

FIG. 1. FINISHING BOARD.

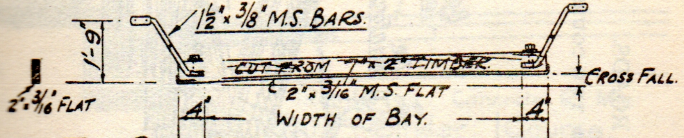

1½"×⅜" M.S. BARS.
1'-9"
CUT FROM 7"×2" TIMBER
2"×3/16" M.S. FLAT
CROSS FALL.
2"×3/16" FLAT
4"
WIDTH OF BAY.
4"

FIG. 2. HAND TAMPER FOR TOP COURSE.

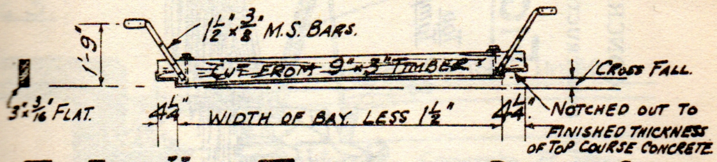

1½"×⅜" M.S. BARS.
1'-9"
CUT FROM 9"×3" TIMBER
CROSS FALL.
3"×3/16" FLAT.
4¼"
WIDTH OF BAY LESS 1½"
4¼"
NOTCHED OUT TO FINISHED THICKNESS OF TOP COURSE CONCRETE.

FIG 3. HAND TAMPER FOR BOTTOM COURSE.

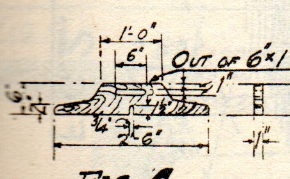

1'-0"
6"
OUT OF 6"×1" TEAK.
1"
6"
¾"
2'-6"
½"

FIG. 4. STRAIGHT EDGE FOR TRUEING TRANSVERSE JOINT.

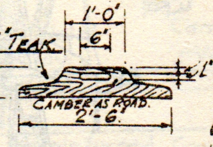

1'-0"
6"
1"
CAMBER AS ROAD.
2'-6"

FIG. 5. TEMPLATE FOR TRUEING LONG^L CENTRE JT.

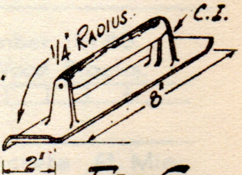

1¼" RADIUS.
C.I.
8"
2"

FIG. 6. EDGING TOOL.

CONCRETE ROADS.

STEPS IN CONSTRUCTION OF TWO-COURSE WORK.

FIG. 1.

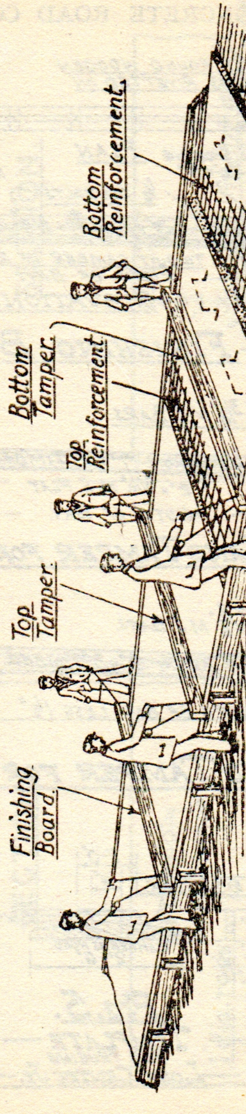
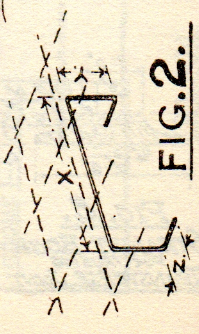
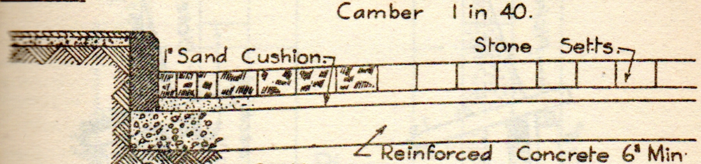

Bottom Reinforcement.
Bottom Tamper.
Top Reinforcement.
Top Tamper.
Finishing Board.

FIG. 2.



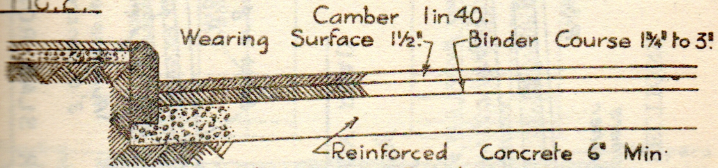
SECTIONS OF PAVED ROADWAYS.

FIG. 1.


Camber 1 in 40.
1" Sand Cushion.
Stone Setts.
Reinforced Concrete 6" Min.

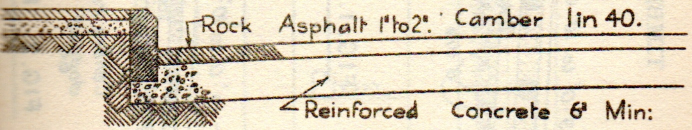
Stone Setts.

FIG. 2.


Camber 1 in 40.
Wearing Surface 1½".
Binder Course 1¾" to 3".
Reinforced Concrete 6" Min.

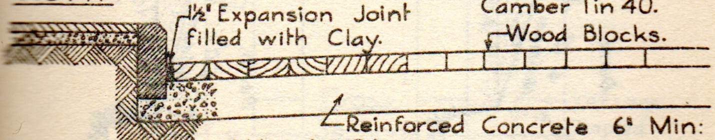
Asphalt with Binder Course.

FIG. 3


Rock Asphalt 1" to 2".
Camber 1 in 40.
Reinforced Concrete 6" Min:

Rock Asphalt.

FIG. 4.


1½" Expansion Joint filled with Clay.
Camber 1 in 40.
Wood Blocks.
Reinforced Concrete 6" Min:

Wood Blocks.

TIMBER ROAD SECTIONS.

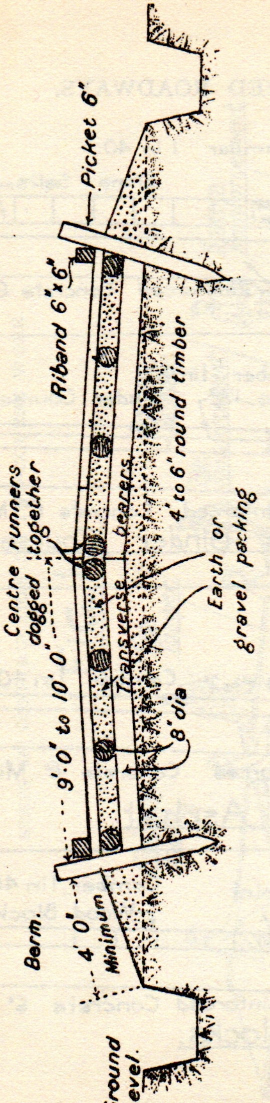

Picket 6"
Riband 6"×6"
Centre runners dogged together
Transverse bearers
4' to 6" round timber
Earth or gravel packing
8" dia
9'0" to 10'0"
4'0"
Berm.
Minimum
Ground Level

FIG. 1. CORDUROY ROAD

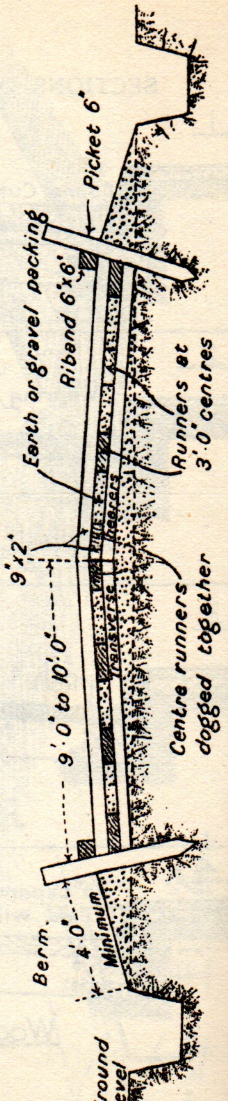
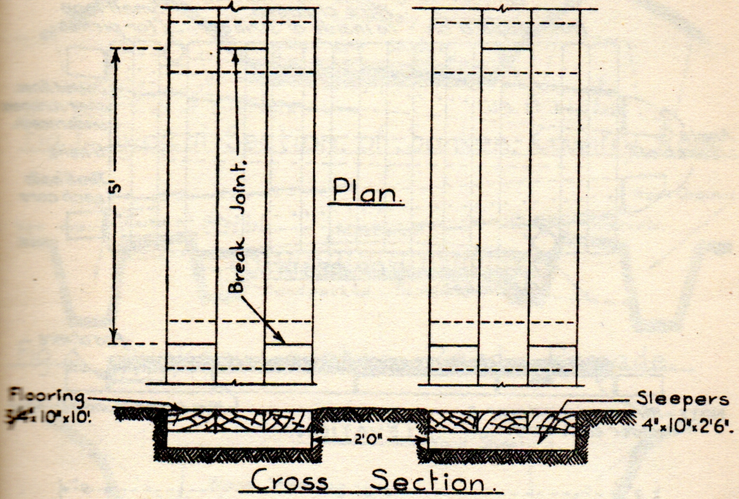

Picket 6"
Earth or gravel packing
Riband 6"×6"
Runners at 3'0" centres
9"×2"
Transverse bearers
Centre runners dogged together
9'0" to 10'0"
4'0"
Berm.
Minimum
Ground Level

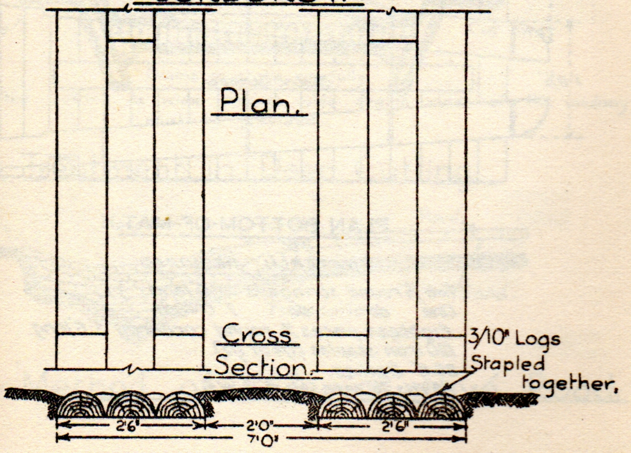
FIG. 2. PLANK OR SLAB ROAD

WHEEL-TRACK ROADS.

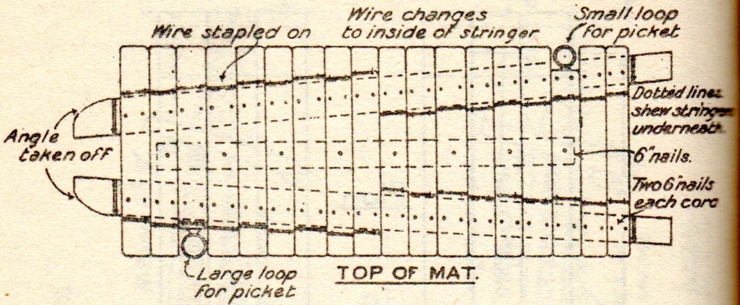
PLANKS.


5'
Break Joint.
Plan.
Flooring 5'×10"×10'
Sleepers 4"×10"×2'6".
2'0"
Cross Section.

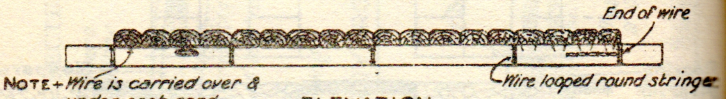
CORDUROY.


Plan.
Cross Section.
3/10" Logs Stapled together,
2'6"
2'0"
2'6"
7'0"

CORDUROY ROAD MAT.

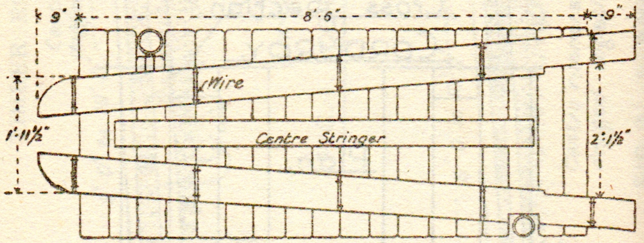

Wire stapled on
Wire changes to inside of stringer
Small loop for picket
Dotted lines shew stringers underneath.
Angle taken off
6" nails.
Two 6" nails each cord
Large loop for picket

TOP OF MAT.


End of wire
Wire looped round stringer

NOTE + Wire is carried over & under each cord.

ELEVATION.


9"
8'·6"
9"
Wire
1'·11½"
Centre Stringer
2'·1½"

PLAN BOTTOM OF MAT.

MATERIAL REQUIRED

Two ½ round stringers 10'·0" long.
One do do 7'·0"—do—
Eighteen pieces ½ round corduroy 3'·6" long
120 Iron staples (1¼" or 1½").
80 6" Spikes.
25 Yds. ¼ wire. No. 4. S.W.G.

IMPROVEMENT OF COUNTRY ROADS.

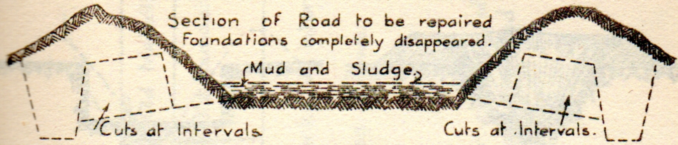

Section of Road to be repaired Foundations completely disappeared.
Mud and Sludge.
Cuts at Intervals.
Cuts at Intervals.

Fig. 1. Typical Section of Sunken Country Road.

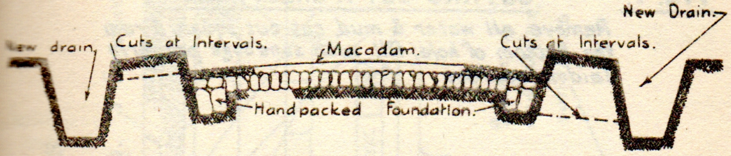
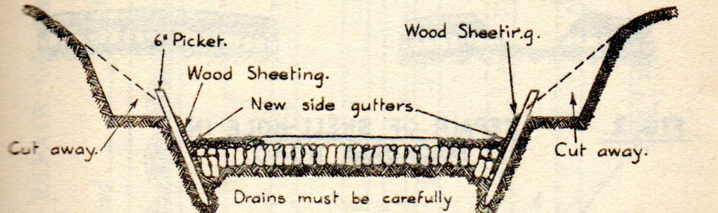

New drain.
Cuts at Intervals.
Macadam.
Cuts at Intervals.
New Drain.
Handpacked Foundation.

Fig. 2. Sunken Country Road Remade.


6" Picket.
Wood Sheeting.
Wood Sheeting.
New side gutters.
Cut away.
Cut away.

Drains must be carefully graded; if the cutting is wide enough, side drains clear of the roadway must be provided.

Fig. 3. Treatment in Deep Cutting.

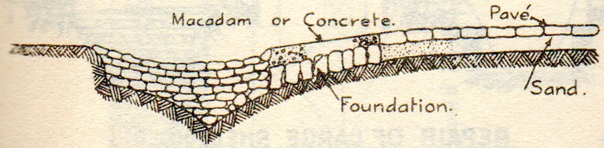

Macadam or Concrete.
Pavé.
Sand.
Foundation.

Fig. 4. Method of Widening Pavé Road.

REPAIR OF SHELL-HOLES.

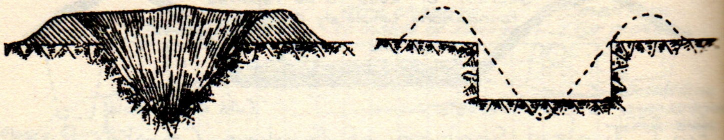


FIG. 1. CUTTING OUT A SHELL-HOLE.

Remove all water & mud, cut out square & ram the bottom of hole; fill with sandbags properly laid in courses.

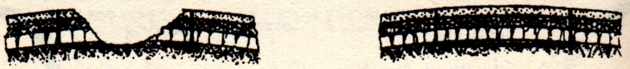


FIG. 2. REPAIR OF SHELL-HOLE IN MACADAM ROAD.

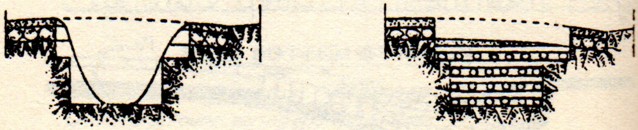
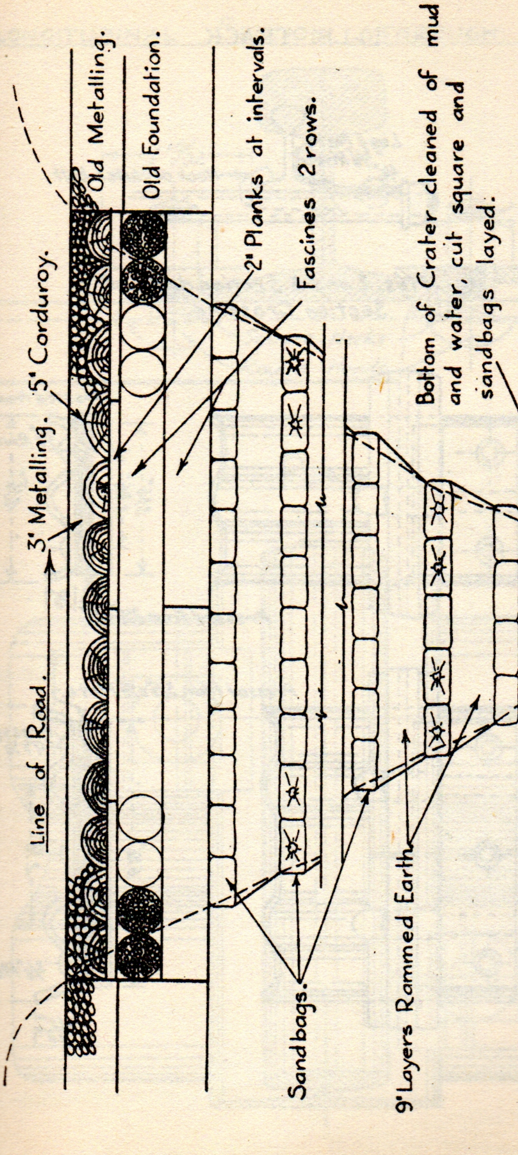


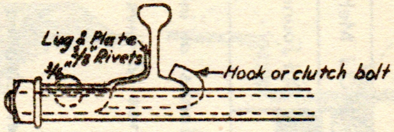
FIG. 3 REPAIR OF LARGE SHELL-HOLE WITH TIMBER CRIB.

REPAIR OF CRATERS.


Line of Road.
3' Metalling.
5' Corduroy.
Old Metalling.
Old Foundation.
2" Planks at intervals.
Fascines 2 rows.
Sandbags.
9" Layers Rammed Earth
Bottom of Crater cleaned of mud and water, cut square and sandbags layed.

10-LB. TRACK.

Fig. 1.


Lug & Plate
3/8" Rivets
3/16"
Hook or clutch bolt

Figs. 2 and 3 Section detail of Section Crossing.

Fig 2.

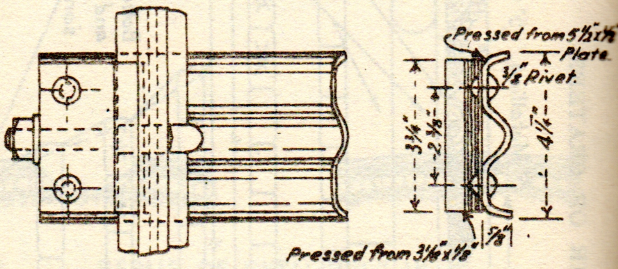
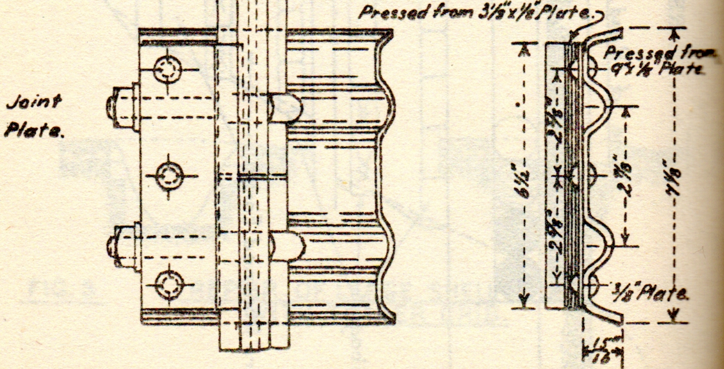
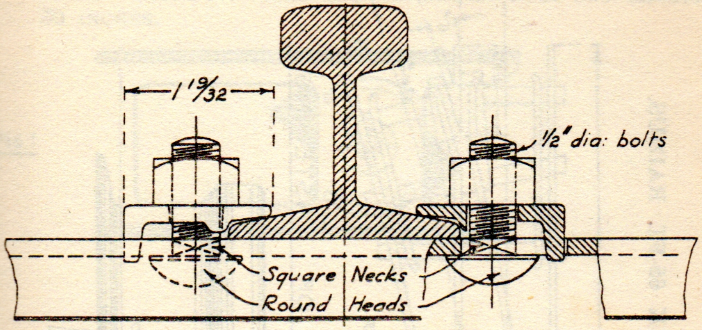

Pressed from 5½"x½" Plate
3/8" Rivet.
3¾"
2⅞"
4½"
5/8"
Pressed from 3 1/16"x1/8"

Fig. 3.

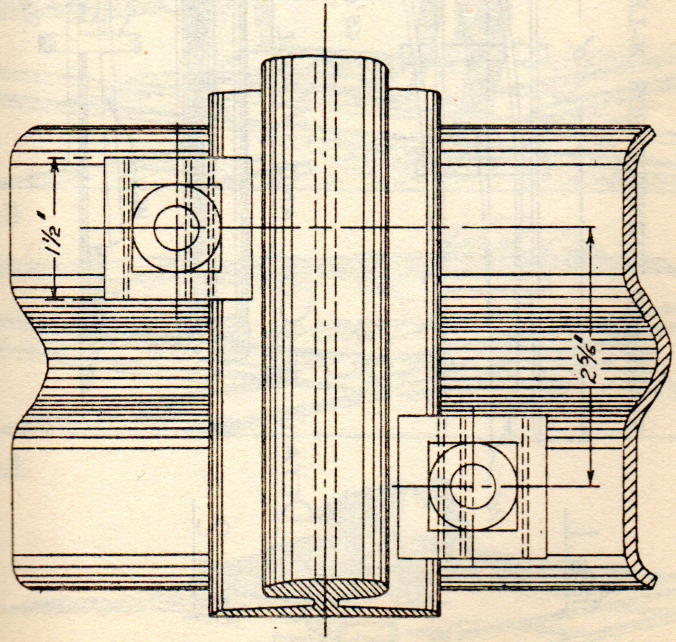

Joint Plate.
Pressed from 3½"x⅛" Plate.
Pressed from 9"x⅛" Plate.
6½"
2⅞"
2⅞"
2⅞"
7⅛"
3/8" Plate.
15/16"

20-LB. TRACK.

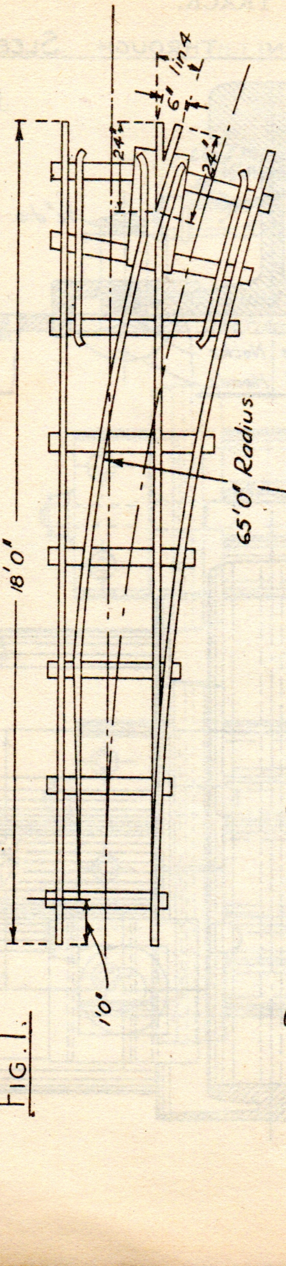
LONGITUDINAL SECTION THROUGH SLEEPER.


1' 9/32
½" dia: bolts
Square Necks
Round Heads

PLAN.



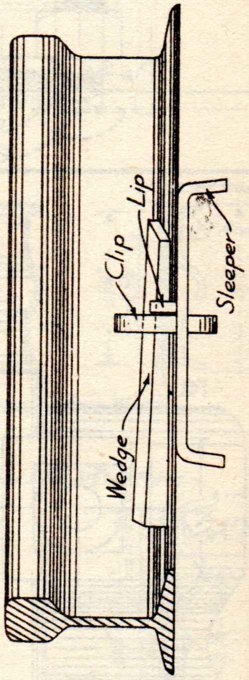
STANDARD TURNOUT FOR 20-LB. TRACK 65-FT. RADIUS.



24"
6"
1 in 4
24"
18'0"
65'0" Radius
10'

FIG. 1.

DETAIL OF CLIP AND WEDGE TYPE OF FASTENING.



Lip
Clip
Sleeper
Wedge

FIG. 2.

PORTABLE LIGHT TURNTABLE.

FOR LIGHT PORTABLE RAILWAY TRACKS UP TO 2′ GAUGE, AND LIGHT WAGONS PROVIDED THE WHEELBASE DOES NOT EXCEED 30 INCHES.

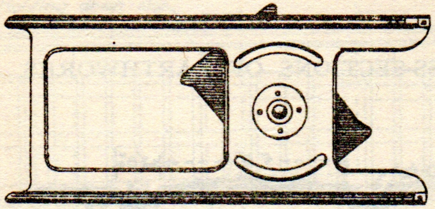


FIG. 1

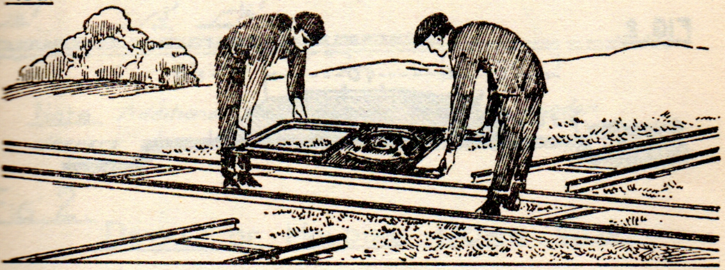


FIG. 2.

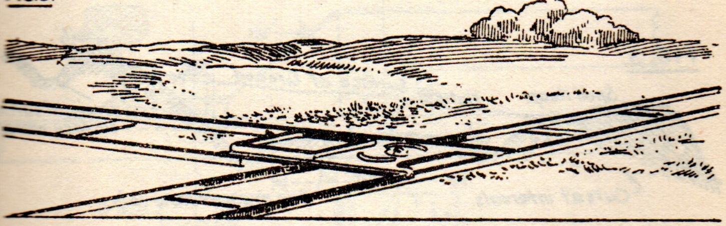


FIG. 3.

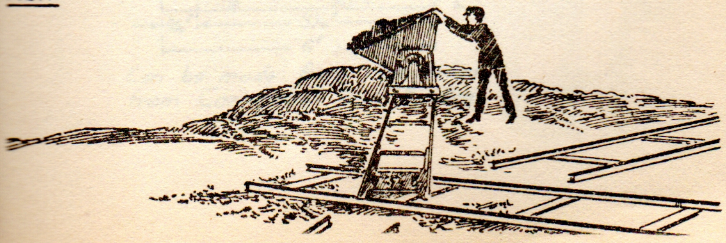


FIG. 4.

CROSS-SECTIONS OF EARTHWORKS.

FIG. 1.

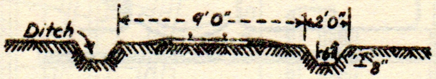

Ditch
9'0"
2'0"
6"
1'8"

FIG. 2.

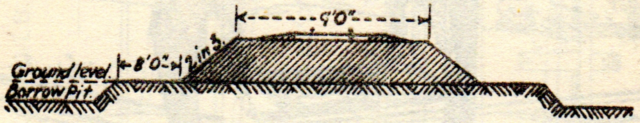
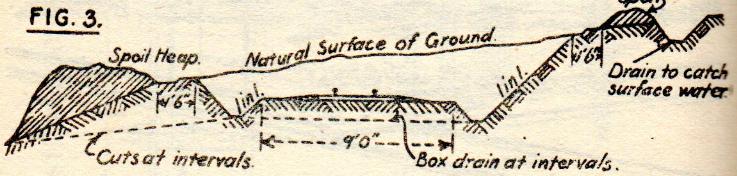
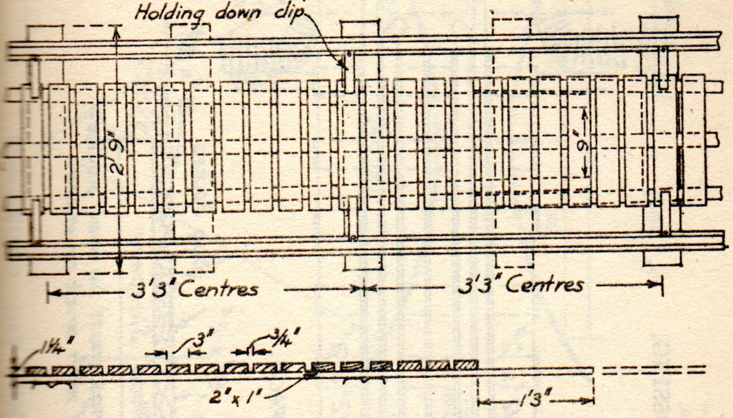

9'0"
Ground level.
Borrow Pit.
8'0"
1 in 3.

FIG. 3.


Spoil
Spoil Heap.
Natural Surface of Ground.
1'6"
1 in 1.
1 in 1.
1'6"
Drain to catch surface water.
9'0"
Cuts at intervals.
Box drain at intervals.

MULE WALK 20-LB. TRACK.

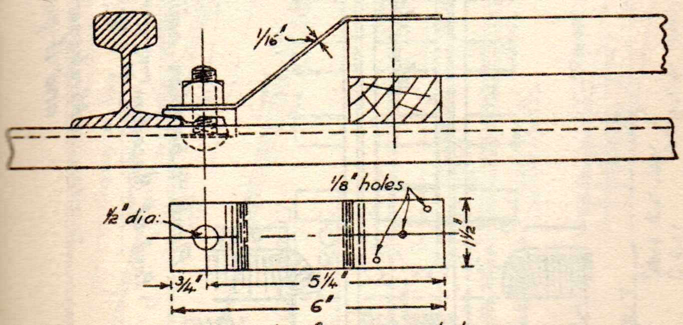
FIG. 1.


Holding down clip
2'9"
9"
3'3" Centres
3'3" Centres
1¼"
3"
¾"
2" x 1"
1'3"

Note. Additional steel sleepers added or wooden sleepers placed between steel sleepers..

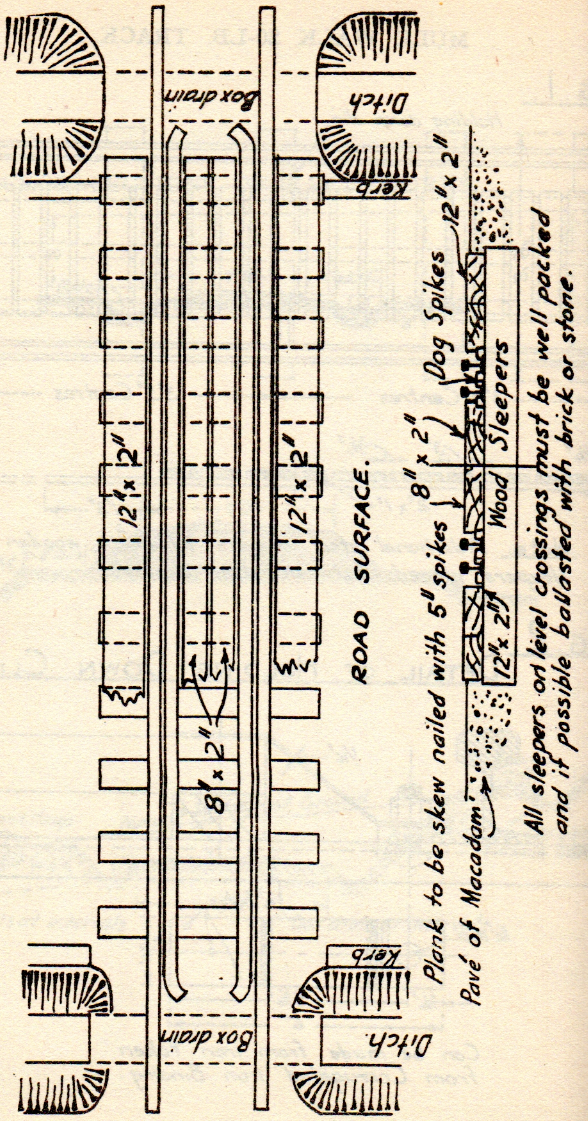
FIG. 2.

DETAIL OF HOLDING DOWN CLIP.


1/16"
⅛" holes
½" dia.
1½"
¾"
5¼"
6"

Can be made from iron taken from Corrugated Iron Binding.

LEVEL CROSSING.

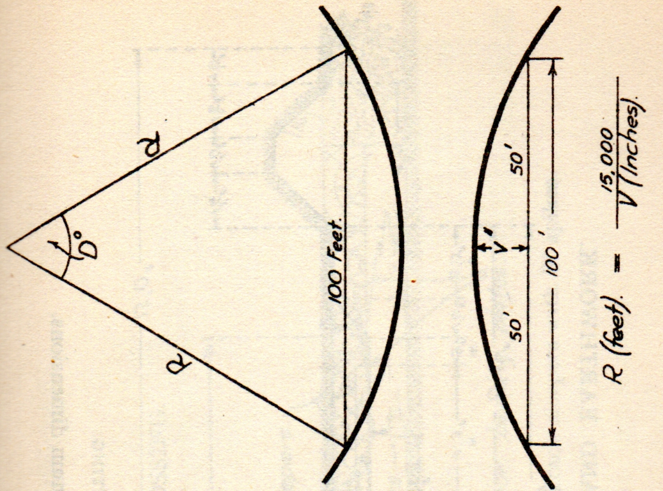

Box drain
Ditch
Kerb
12″ x 2″
12″ x 2″
8″ x 2″
ROAD SURFACE.
12″ x 2″
8″ x 2″
12″ x 2″
Dog Spikes
Wood Sleepers
Box drain
Ditch
Kerb

Plank to be skew nailed with 5″ spikes

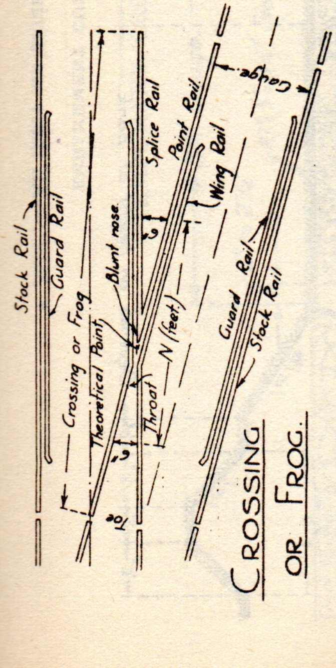
Pavé of Macadam

All sleepers on level crossings must be well packed and if possible ballasted with brick or stone.

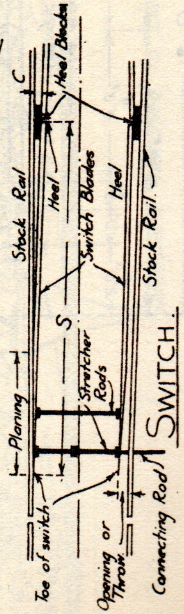
NOMENCLATURE OF SWITCHES AND CROSSINGS.


R
R
D°
100 Feet.
50'
100'
50'
V″

$$R\ (\text{feet}) = \frac{15{,}000}{V\ (\text{inches})}$$


Stock Rail
Guard Rail
Crossing or Frog
Theoretical Point
Blunt nose.
Toe
Throat
N (feet)
Splice Rail
Point Rail
Wing Rail
Gauge
Guard Rail
Stock Rail

CROSSING OR FROG.


C
Heel Blocks
Stock Rail
Heel
Switch Blades
Heel
Stock Rail
S
Planing
Stretcher Rods
Toe of switch
Opening or Throw
Connecting Rod

SWITCH.

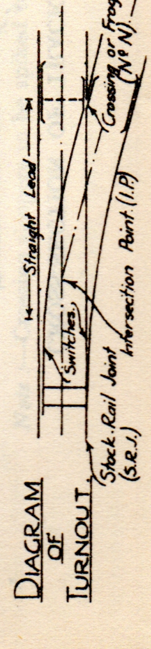
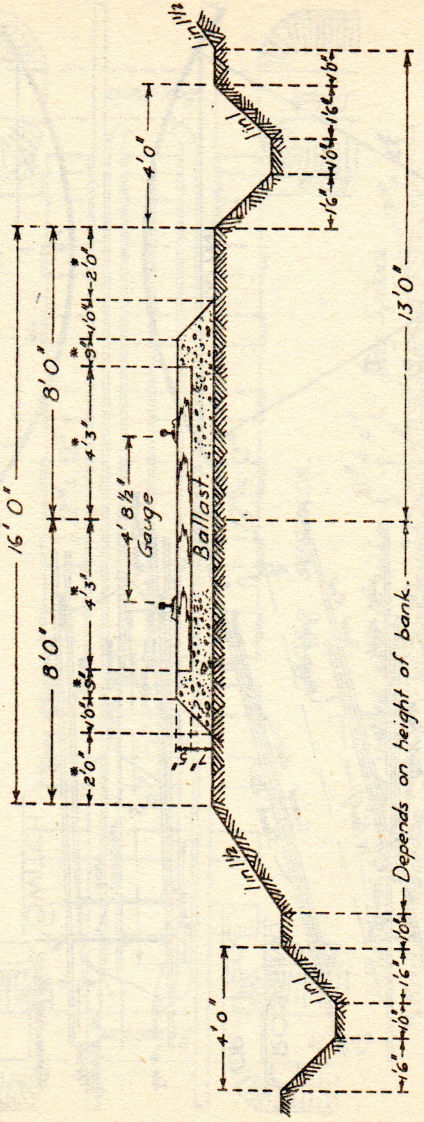

Crossing or Frog (Nº N)
Straight Lead
Switches
Stock Rail Joint (S.R.J.)
Intersection Point (I.P.)

DIAGRAM OF TURNOUT.

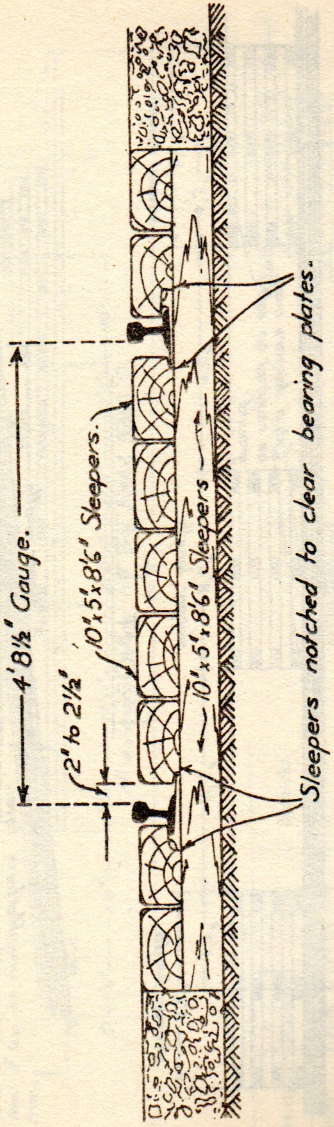
CROSS-SECTION OF TRACK AND EARTHWORK.


1 in 1½
1 in 1
4'0"
1'6"
1'0"
1'6"
1'0"
16'0" *
8'0"
8'0"
2'0" *
1'0"
9" *
4'3" *
4'3" *
4' 8½" Gauge
Ballast.
7"
5"
13'0"
Depends on height of bank.

EMBANKMENT CUTTING.

* *Note* :—All these are minimum dimensions.

TEMPORARY CROSSING.

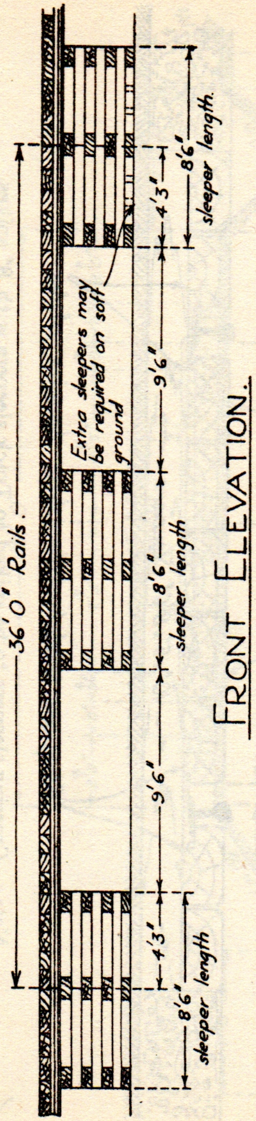

4'8½" Gauge.
2" to 2½"
10'×5'×8'6" Sleepers.
10'×5'×8'6" Sleepers
Sleepers notched to clear bearing plates.

Note :—Crossing sleepers to be spiked to Track sleepers with 8" spikes.

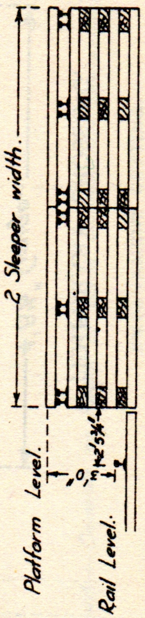
CRIB PIER PLATFORM.

FOR USE WITH STANDARD 4′ 8½″ GAUGE TRACK.

Made up of 36′ 0″ Rails and Sleepers.


36′ 0″ Rails.
4′3″
8′6″ sleeper length.
9′6″
Extra sleepers may be required on soft ground
8′6″ sleeper length
9′6″
4′3″
8′6″ sleeper length

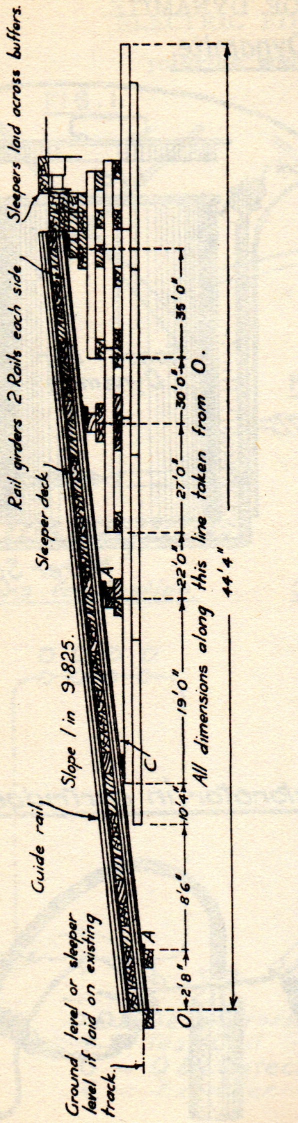
FRONT ELEVATION.

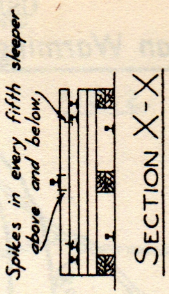

2 Sleeper width.
Platform Level.
0′ 11″
2′5¾″
Rail Level.

END ELEVATION.

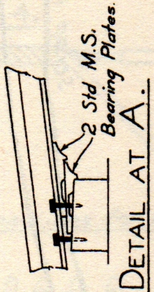
TYPICAL END LOADING RAMP.

SUITABLE FOR ALL MILITARY LOADS.


Sleepers laid across buffers.
Rail girders 2 Rails each side
Sleeper deck
A
C
A
Guide rail
Slope 1 in 9·825.
Ground level or sleeper level if laid on existing track.
35′0″
30′0″
27′0″
22′0″
19′0″
10′4″
8′6″
2′8″
0
All dimensions along this line taken from O.
44′4″


Spikes in every fifth sleeper above and below.

SECTION X-X


2 Std M.S. Bearing Plates.

DETAIL AT A.

Detail at C similar to above except that rib of bearing plate is let into sleeper.

SCHEDULE OF MATERIALS.

No. off	Description	Material	Size	Remarks
5	Rails	R.S.	75 lb. × 36′	
120	Sleepers	Timber	10″ × 5″ × 8′ 6″	
20	Bearing Plates	C.I.	75 lb.	Including approach road.
130	Dog Spikes	M.S.	Std.	

USE OF DYNAMITE.

Fig. 1. Pan Warming Dynamite.

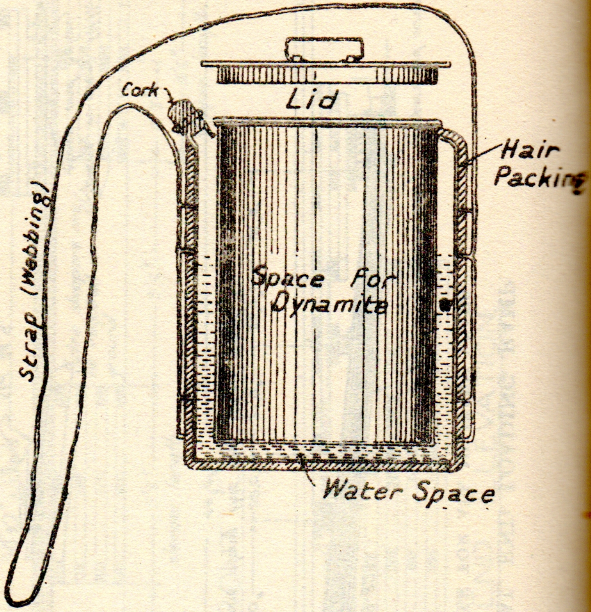
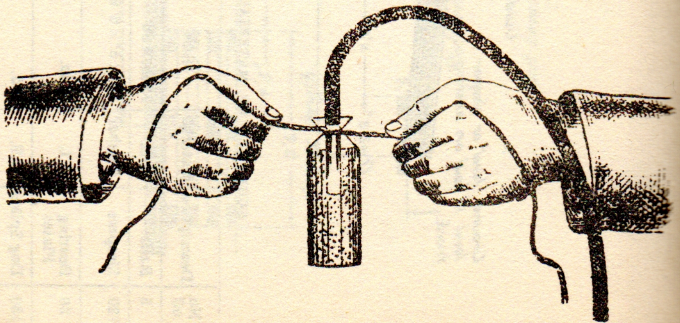

Lid
Cork
Hair Packing
Strap (Webbing)
Space for Dynamite
Water Space

Fig. 2. Insertion of detonator in cartridge.



ELECTRIC FIRING.

JOINTING WIRES.

FIG. 1.

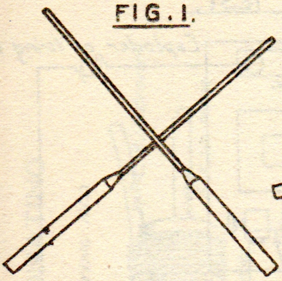


FIG. 2.

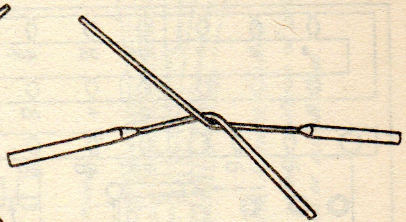


FIG. 3.

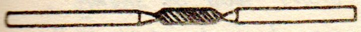
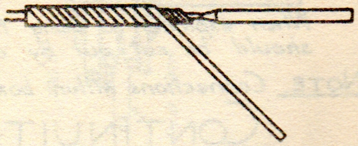


FIG. 4.



Connections for testing.

Connections for firing.

FIG. 5.

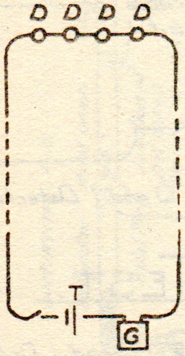
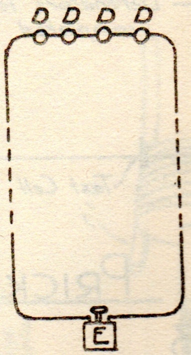


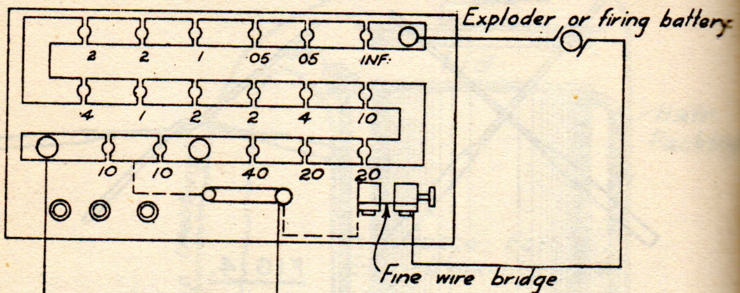
FIG. 6.



D.D. = Detonators in charge.
T = Test Cell.
G = Q & I. Detector.
E = Exploder.

FUSION TEST.

FIG. 1. BOX OF RESISTANCE COILS CONNECTED UP FOR FUSION TEST.

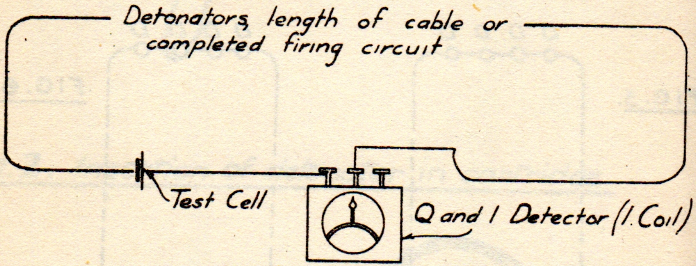

Exploder or firing battery
2
2
1
.05
.05
INF:
.4
1
2
2
4
10
10
10
40
20
20
Fine wire bridge

When exploder is being tested the Contact Key should be cut out by a short lead as shewn.

NOTE. Connections within box are shewn by dotted lines

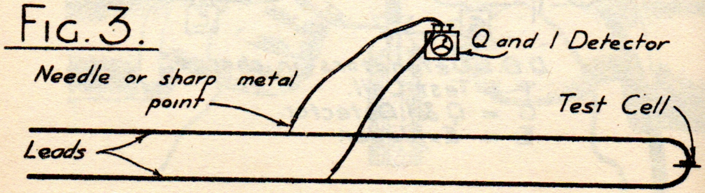
CONTINUITY TEST.

FIG. 2. DIAGRAM OF CONNECTIONS.


Detonators, length of cable or completed firing circuit
Test Cell
Q and I Detector (I. Coil)

PRICKER TEST.

FIG. 3.


Q and I Detector
Needle or sharp metal point
Test Cell
Leads

USE OF FUZE INSTANTANEOUS. DETONATING

INITIATING. F.I.D.

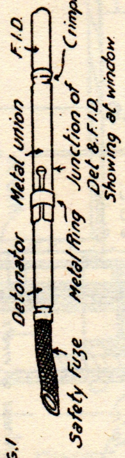

Detonator
Metal union
F.I.D.
Crimping
Junction of Det & F.I.D. Showing at window.
Metal Ring
Safety Fuze

FIG. 1

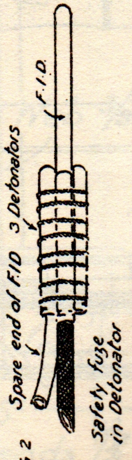

Spare end of F.I.D
3 Detonators
F.I.D.
Safety fuze in Detonator

FIG 2

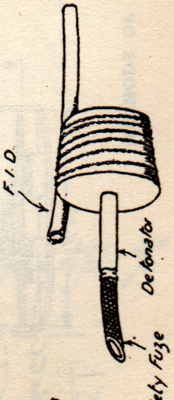

F.I.D.
Detonator
Safety Fuze

FIG. 3

JOINTING F.I.D.

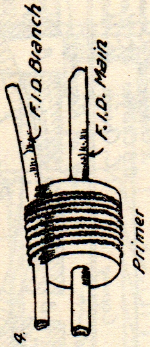

F.I.D. Branch
F.I.D. Main
Primer

FIG. 4.

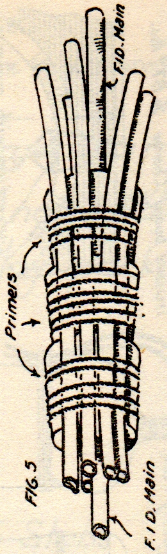

F.I.D. Main
Primers
F.I.D. Main

FIG. 5

Requisite branches lashed tightly along outside of primers by twine or rubber tape.

DEMOLITIONS.

METHODS OF FIXING CHARGE AND DETONATOR.

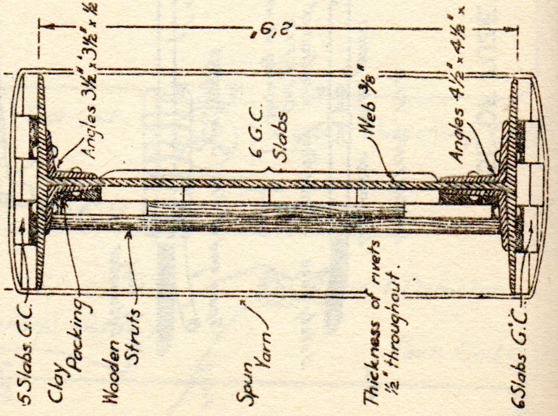

2' 9"
1' 3"
Angles 3½" × 3½" × ½"
6 G.C. Slabs
Web ⅜"
Angles 4½" × 4½" × ⅝"
5 Slabs G.C.
Clay Packing
Wooden Struts
Spun Yarn
Thickness of rivets ½" throughout.
6 Slabs G.C.

FIG. 1.

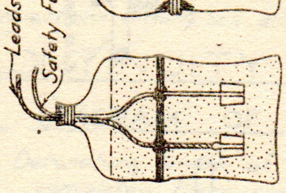

Leads
Safety Fuse

FIG. 2.

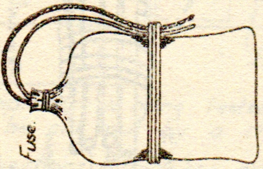


FIG. 3.

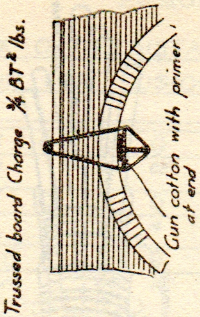

Trussed board Charge ¾ BT² lbs.
Gun cotton with primer at end

FIG. 4.

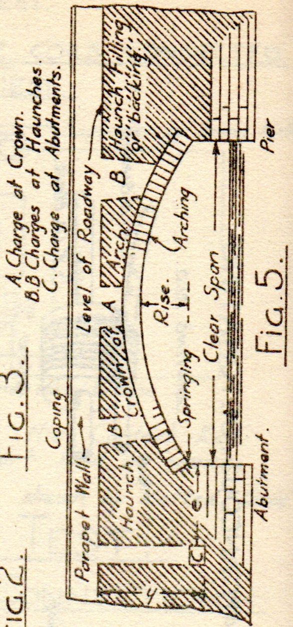
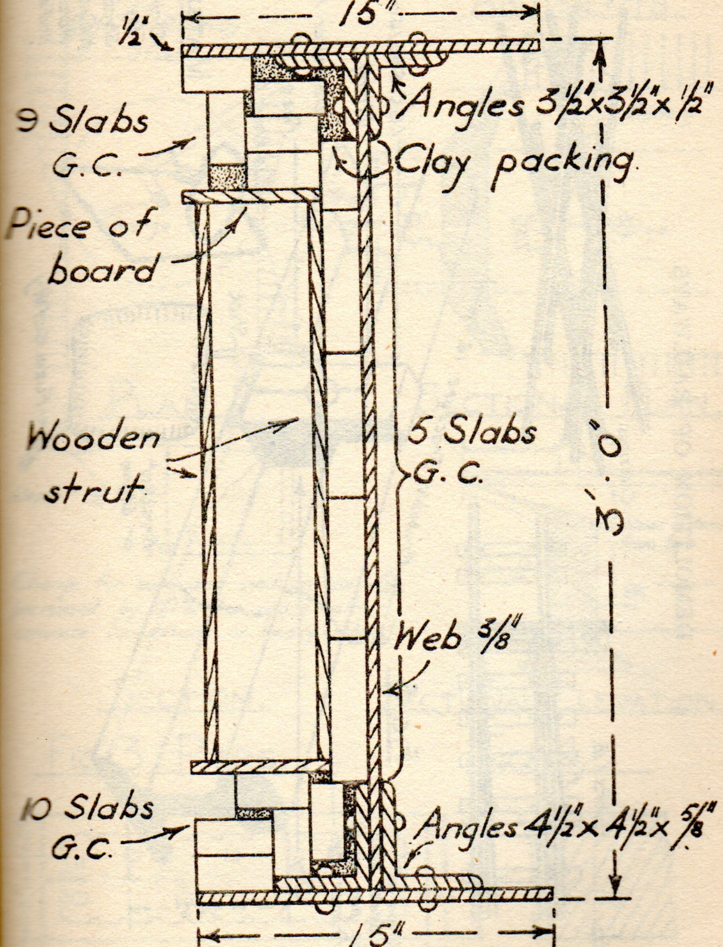

A. Charge at Crown.
B.B. Charges at Haunches.
C. Charge at Abutments.
Level of Roadway
Filling
Haunch Filling or backing
Crown of Arch
A
B
B
C
Rise
Arching
Springing
Clear Span
Coping
Parapet Wall
Haunch
e
y
Abutment
Pier

FIG. 5.

DEMOLITIONS.

METHOD OF FIXING A CHARGE TO A GIRDER.


15"
½"
9 Slabs G.C.
Angles 3½" × 3½" × ½"
Clay packing
Piece of board
Wooden strut
5 Slabs G.C.
3' 0"
Web ⅜"
10 Slabs G.C.
Angles 4½" × 4½" × ⅝"
15"

Thickness of rivet heads ½" throughout.

DEMOLITION OF RAILWAYS.

FIG. 2.

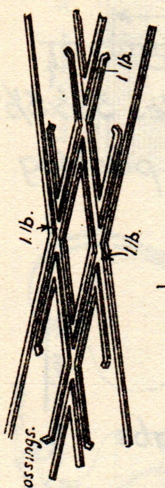
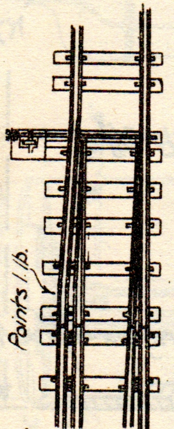

1 lb.
1 lb.
1 lb.
Crossings.

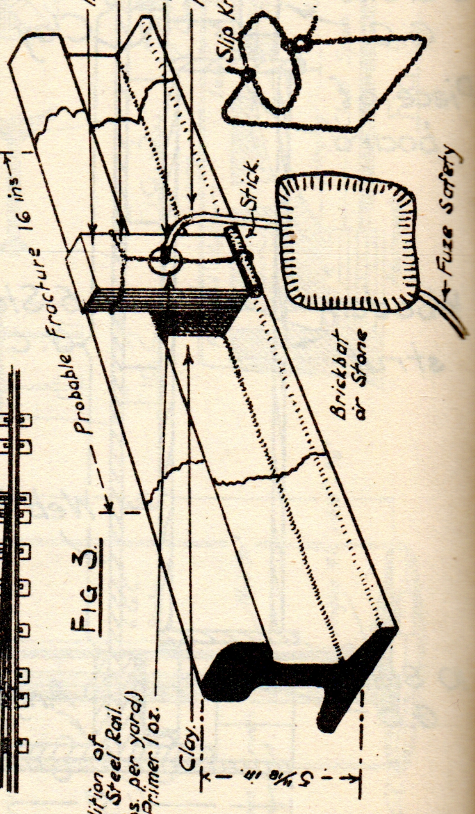
FIG. 1.



MATERIALS.

String 3 ft.
Clay
Stick
Weight.
Matches.
Knife.

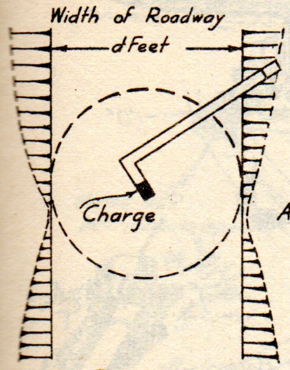
FIG 3.


1 G.C. Slab. 16 oz.
String
1 Detonator No 8.
Fuze.
Slip Knot.
Stick.
Fuze Safety
Brickbat or Stone
Probable Fracture 16 ins
Clay.
5 11/16 ins

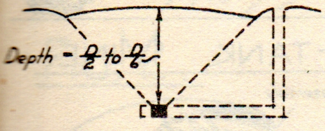
Demolition of Heavy Steel Rail. (105 lbs. per yard) 1 G.C. Primer 1 oz.

MINED CHARGES.

FIG. 1. ROADS, ETC.


Width of Roadway
d Feet
Charge

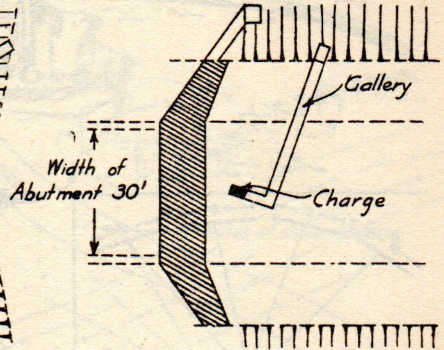
PLAN.


Depth = D/2 to D/6

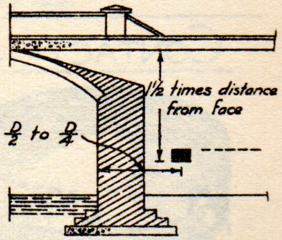
Charge for soft and medium soil $= \frac{D^3}{100}$ (increased by 50% for roads with concrete foundations or heavy soling.)

SECTION.

FIG. 2. BRIDGE ABUTMENTS.


Gallery
Width of Abutment 30'
Charge

SECTIONAL PLAN.


1½ times distance from face
D/2 to D/4

SECTIONAL ELEVATION.

FIG. 3. PIERS.

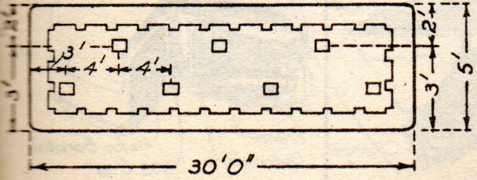
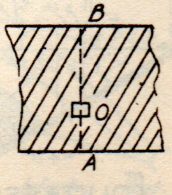
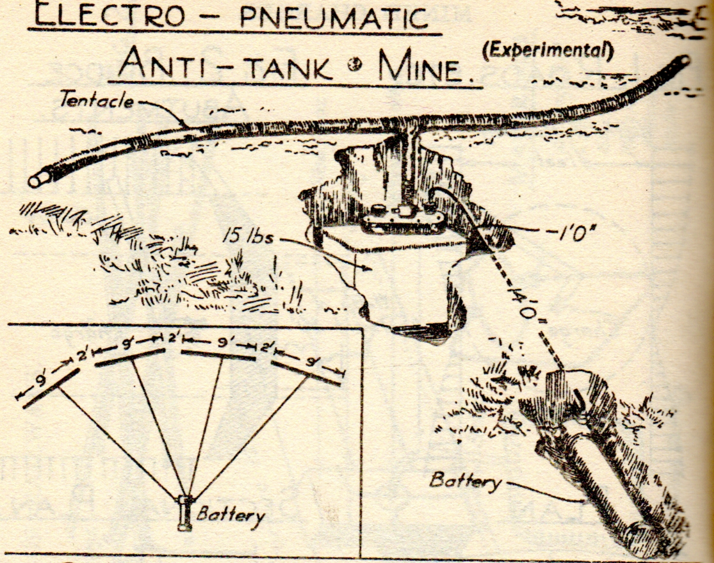

2'
3'
4'
4'
2'
5'
3'
3'
30'0"

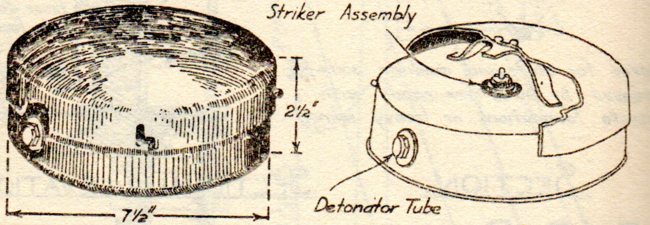
FIG. 4.

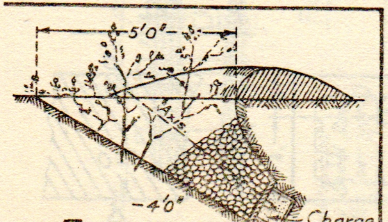


ELECTRO-PNEUMATIC ANTI-TANK MINE. (Experimental)

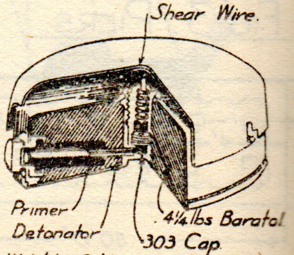

Tentacle
15 lbs
1'0"
4'0"
9'
2'
9'
2'
9'
2'
9'
Battery
Battery

CONTACT ANTI-TANK MINE.


Striker Assembly
2½"
7½"
Detonator Tube


5'0"
4'0"
Charge

FOUGASSE.


Shear Wire.
Primer
Detonator
4¼ lbs Baratol
303 Cap.

Weight of Mine = 8lbs.

USE OF ANTI-TANK MINES FOR A ROAD BLOCK.

FIG. 1.

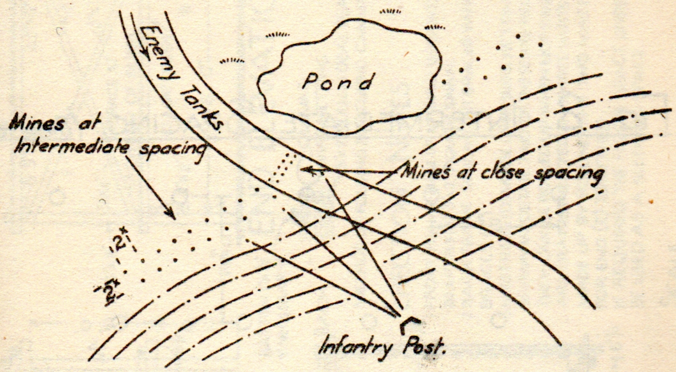
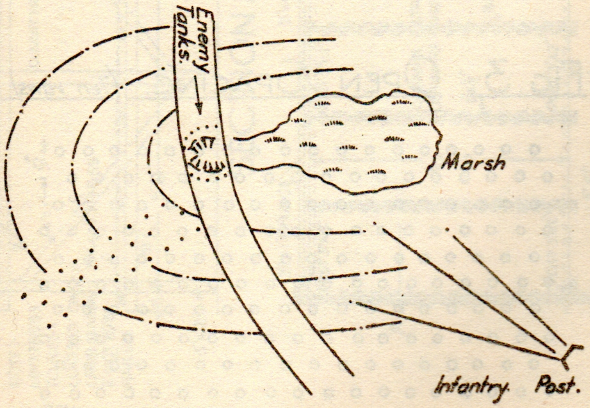

Enemy Tanks.
Pond
Mines at Intermediate spacing
Mines at close spacing
2'
2'
Infantry Post.

FIG. 2.


Enemy Tanks.
Marsh
Infantry Post.

SPACING OF A.T. MINES.

FIG. 1. CLOSE SPACING. (*Double row*).

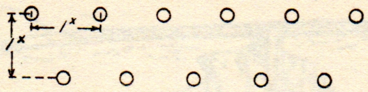


FIG. 2. INTERMEDIATE SPACING. (*Three rows*).

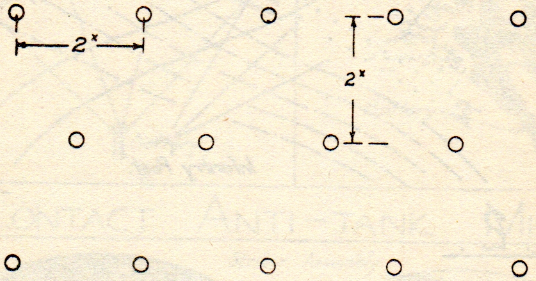
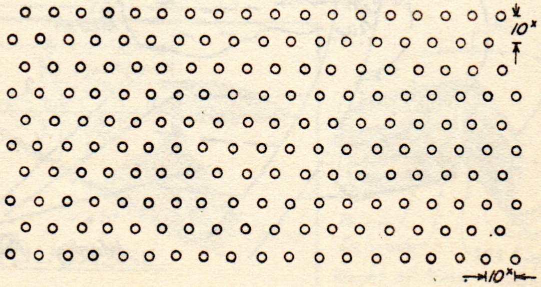
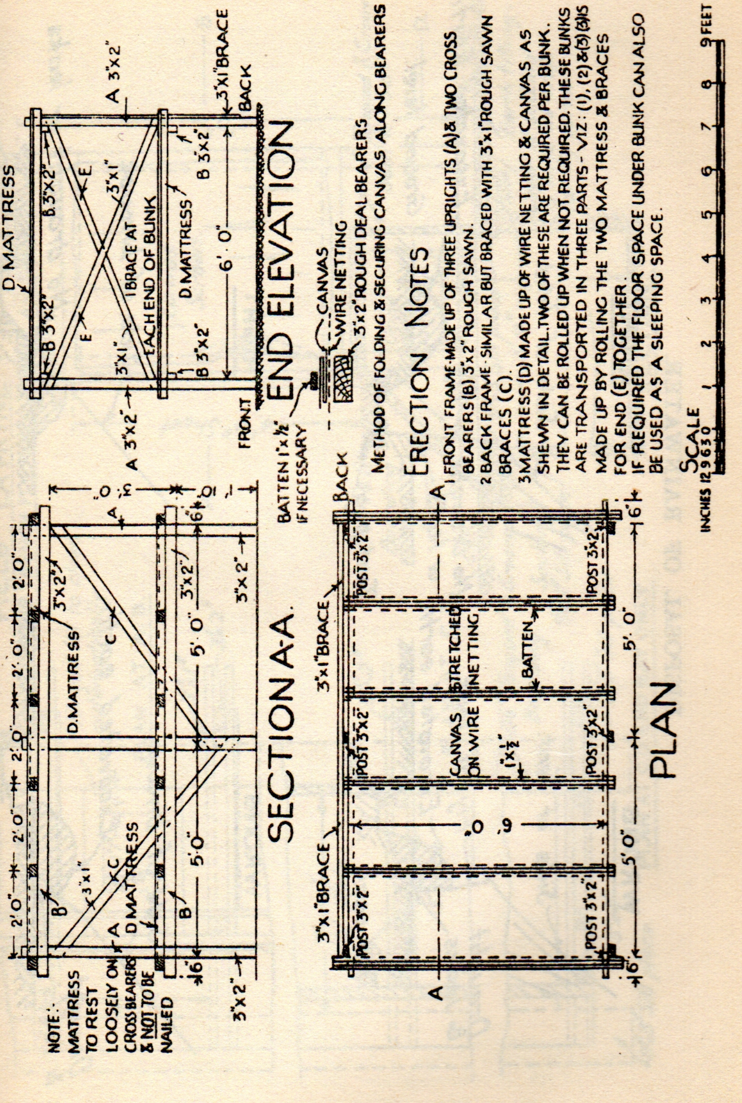


FIG. 3. OPEN SPACING. (*Ten rows*).



DOUBLE BUNK FOR 10 MEN.


END ELEVATION
D. MATTRESS
B 3"x2"
E
3"x1"
1 BRACE AT EACH END OF BUNK
D. MATTRESS
B 3"x2"
6'. 0"
A 3"x2"
3"x1" BRACE
BACK
FRONT
BATTEN 1"x½" IF NECESSARY
CANVAS
WIRE NETTING
3"x2" ROUGH DEAL BEARERS
SECTION A-A
D. MATTRESS
C
3"x2"
5'. 0"
2'. 0"
6"
3'. 0"
B
NOTE:- MATTRESS TO REST LOOSELY ON CROSS BEARERS & NOT TO BE NAILED
PLAN
BACK
A
3"x1" BRACE
POST 3"x2"
CANVAS ON WIRE NETTING
STRETCHED
BATTEN
1"x½"
6'. 0"
5'. 0"
SCALE
INCHES 12 9 6 3 0
1 2 3 4 5 6 7 8 9 FEET

METHOD OF FOLDING & SECURING CANVAS ALONG BEARERS

ERECTION NOTES

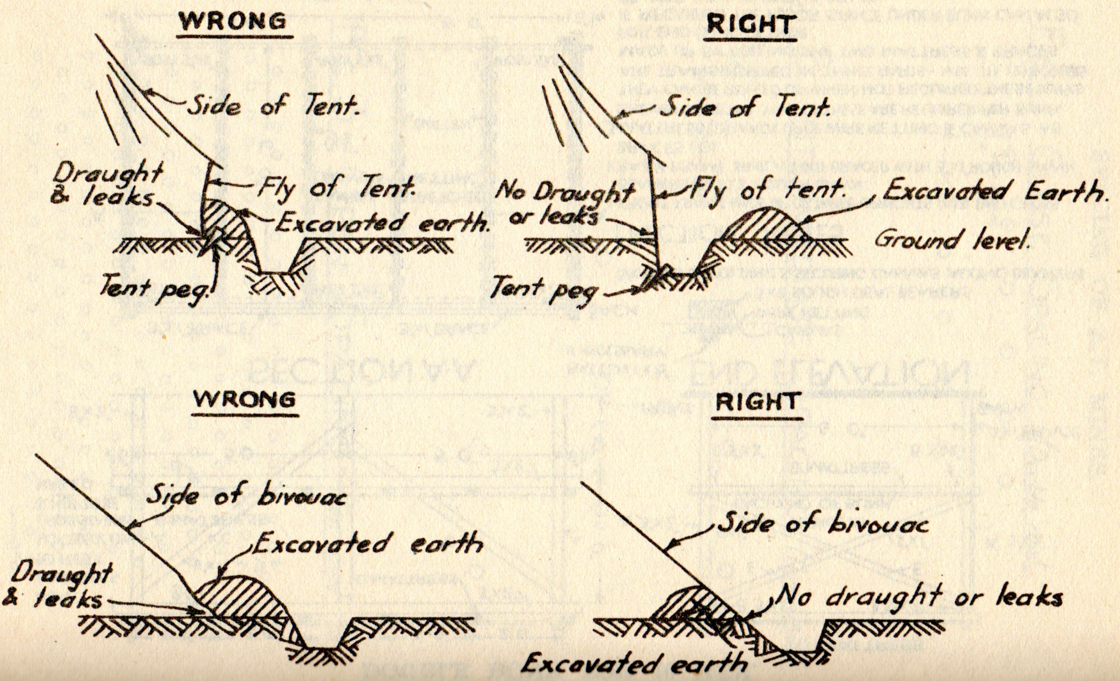
1 FRONT FRAME: MADE UP OF THREE UPRIGHTS (A) & TWO CROSS BEARERS (B) 3"x2" ROUGH SAWN.

2 BACK FRAME: SIMILAR BUT BRACED WITH 3"x1" ROUGH SAWN BRACES (C).

3 MATTRESS (D) MADE UP OF WIRE NETTING & CANVAS AS SHEWN IN DETAIL. TWO OF THESE ARE REQUIRED PER BUNK. THEY CAN BE ROLLED UP WHEN NOT REQUIRED. THESE BUNKS ARE TRANSPORTED IN THREE PARTS - VIZ: (1), (2) & (3) (3) IS MADE UP BY ROLLING THE TWO MATTRESS & BRACES FOR END (E) TOGETHER.

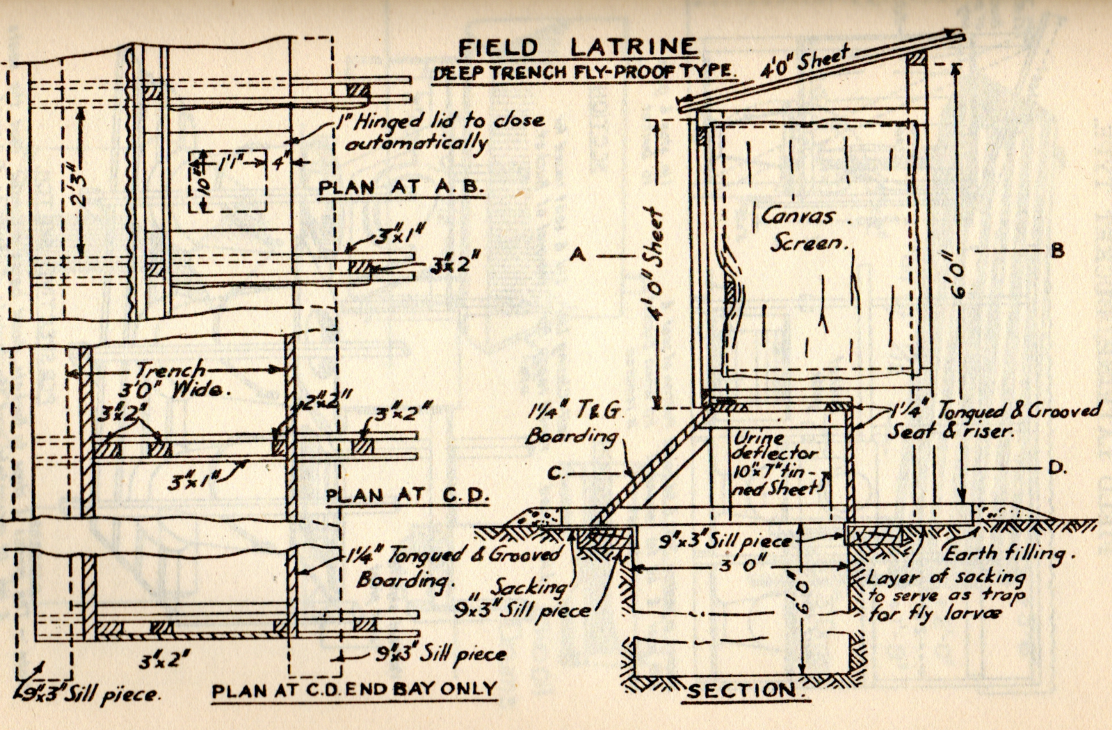
IF REQUIRED THE FLOOR SPACE UNDER BUNK CAN ALSO BE USED AS A SLEEPING SPACE.

DISPOSAL OF RAINWATER.

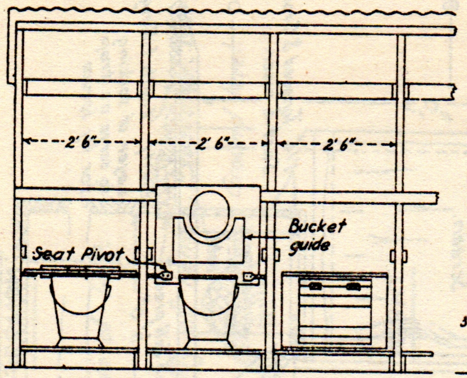

WRONG
Side of Tent.
Draught & leaks
Fly of Tent.
Excavated earth.
Tent peg.
RIGHT
Side of Tent.
No Draught or leaks
Fly of tent.
Excavated Earth.
Ground level.
Tent peg
WRONG
Side of bivouac
Excavated earth
Draught & leaks
RIGHT
Side of bivouac
No draught or leaks
Excavated earth

FIELD LATRINE

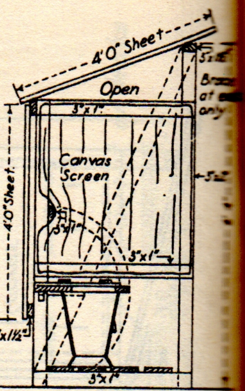
DEEP TRENCH FLY-PROOF TYPE.


4'0" Sheet
1" Hinged lid to close automatically
1'1"
4"
10"
2'3"
PLAN AT A.B.
3"x1"
3"x2"
Trench 3'0" Wide.
3"x2"
2"x2"
3"x2"
3"x1"
PLAN AT C.D.
1¼" Tongued & Grooved Boarding.
3"x2"
9"x3" Sill piece
9"x3" Sill piece.
PLAN AT C.D. END BAY ONLY
A
4'0" Sheet
Canvas Screen.
B
6'0"
1¼" T & G. Boarding
1¼" Tongued & Grooved Seat & riser.
Urine deflector 10"x7" tinned Sheet
C.
D.
9"x3" Sill piece
3'0"
Earth filling.
Sacking
9"x3" Sill piece
Layer of sacking to serve as trap for fly larvæ
6'0"
SECTION.

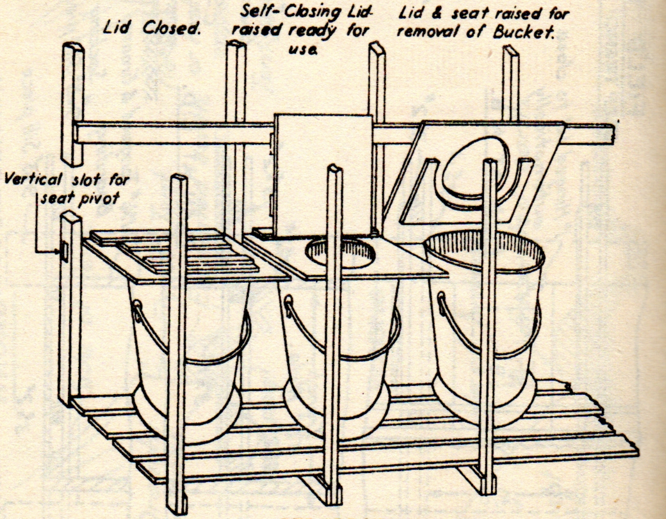
FIELD LATRINE, BUCKET TYPE.


2' 6"
2' 6"
2' 6"
Seat Pivot
Bucket guide
Bucket in position with seat & lid closed.
Seat & lid raised for removal of bucket.
Position of seat & lid when Bucket is removed

ELEVATION


4'0" Sheet
Open
3"x1"
Canvas Screen
4'0" Sheet.
3"x1"
3"x1"
3"x1½"
3"x1"
1 in. stop & guide to bucket.

SECTION


Lid Closed.
Self-Closing Lid raised ready for use.
Lid & seat raised for removal of Bucket.
Vertical slot for seat pivot

PERSPECTIVE SKETCH.

Note :—The guides & stops to Buckets should be so arranged that the seats & lids fit accurately over the Buckets & should be fly-proof.

URINALS.

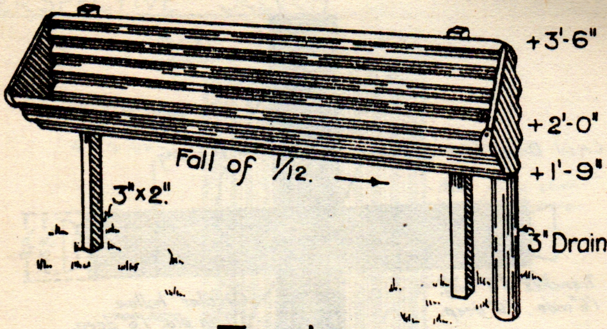

+3'-6"
+2'-0"
+1'-9"
Fall of 1/12.
3"x2."
3" Drain.

Fig. 1.

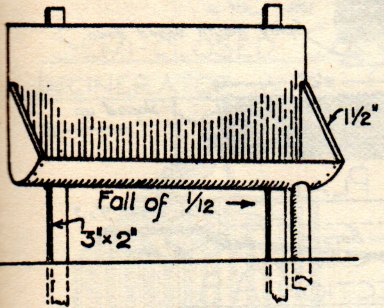

1½"
Fall of 1/12
3"x2"

Fig. 2.

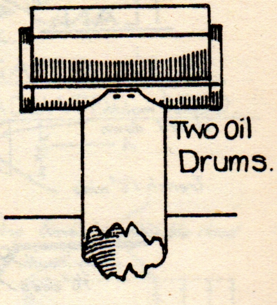

Two Oil Drums.

Fig. 3.

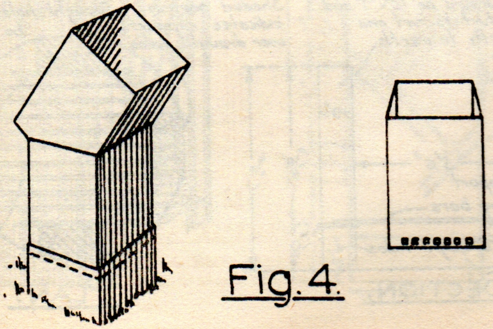
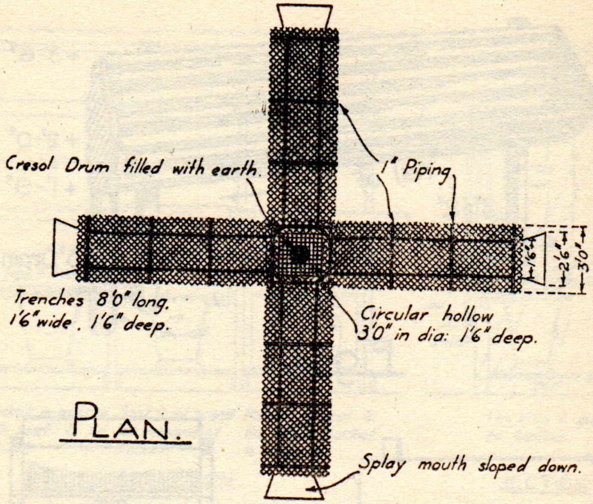
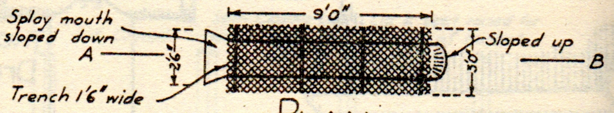


Fig. 4.

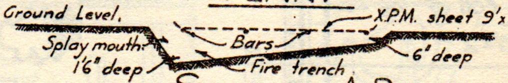
TRENCH MANURE INCINERATOR.


Cresol Drum filled with earth.
1" Piping
Trenches 8'0" long. 1'6" wide. 1'6" deep.
Circular hollow 3'0" in dia: 1'6" deep.
1'6"
2'6"
3'0"
Splay mouth sloped down.

PLAN.

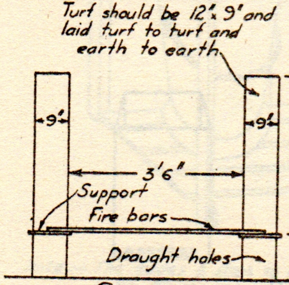

9'0"
Splay mouth sloped down
A
2'6"
3'0"
Sloped up
B
Trench 1'6" wide

PLAN.

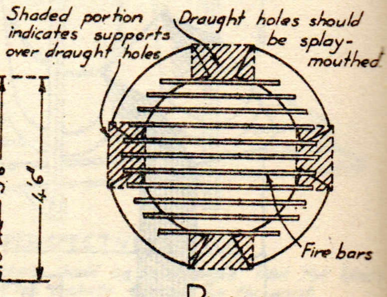

Ground Level.
X.P.M. sheet 9'x3'
Bars
Splay mouth 1'6" deep
Fire trench
6" deep

SECTION A-B.

OPEN CIRCULAR TURF INCINERATOR.

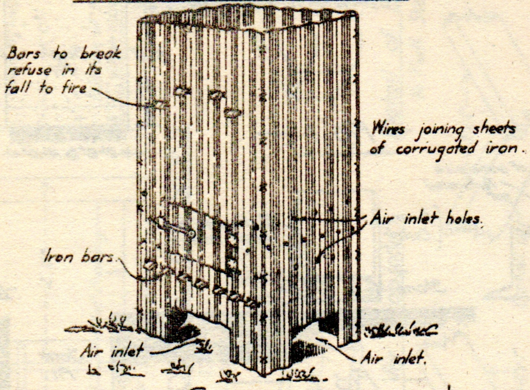

Turf should be 12"x9" and laid turf to turf and earth to earth.
9"
9"
3'6"
3'6"
4'6"
Support
Fire bars
Draught holes
10"

SECTION.

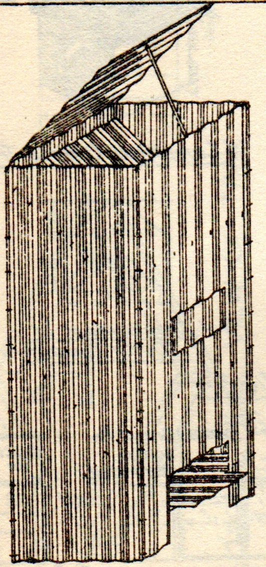

Shaded portion indicates supports over draught holes
Draught holes should be splay-mouthed.
Fire bars

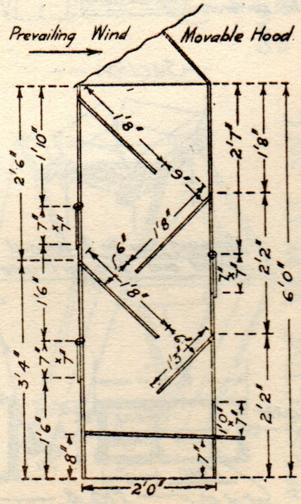
PLAN.

PERSPECTIVE SKETCH OF CORRUGATED IRON INCINERATOR.


Bars to break refuse in its fall to fire
Wires joining sheets of corrugated iron.
Air inlet holes.
Iron bars
Air inlet
Air inlet.

SEMI-CLOSED CORRUGATED IRON INCINERATOR WITH GRADUATED FEED.




Prevailing Wind
Movable Hood
2'6"
1'10"
7"x7"
1'6"
3'4"
7"x7"
1'6"
8"
1'8"
9"
1'8"
6"
1'8"
1'3"
2'7"
1'8"
2'2"
6'0"
7"x7"
2'2"
10"x7"
7"
2'0"

GREASE TRAPS.

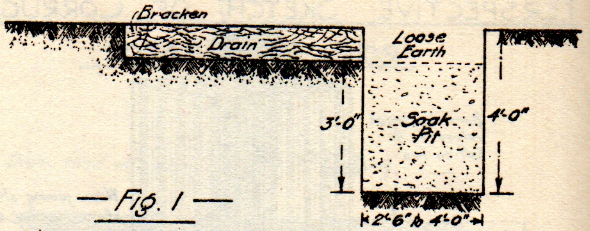

Bracken
Drain
Loose Earth
Soak Pit
3'-0"
4'-0"
2'-6" to 4'-0"

Fig. 1

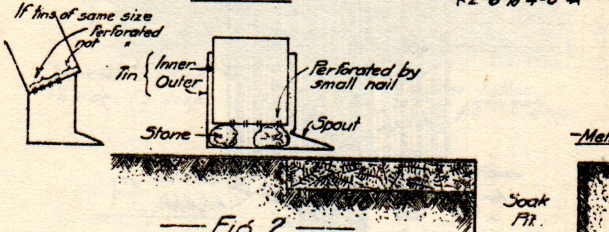
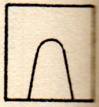
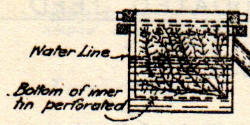

If tins of same size
Perforated
not "
Tin { Inner / Outer
Perforated by small nail
Stone
Spout
Soak Pit.

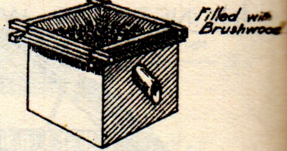
Fig. 2



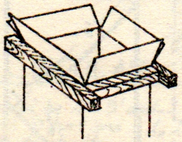
Method of cutting spout


Water Line
Outlet
Bottom of inner tin perforated

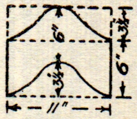
Section.


Filled with Brushwood

Completed Grease Trap



Shewing how Tin is cut and folded over Wooden Frame



Development of Outlet Spout

Fig. 3.

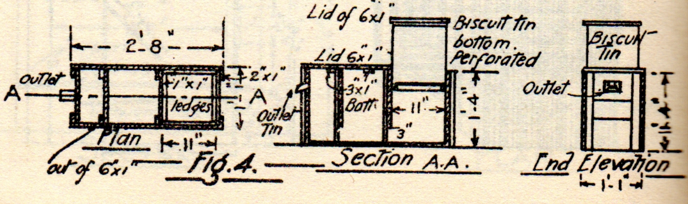
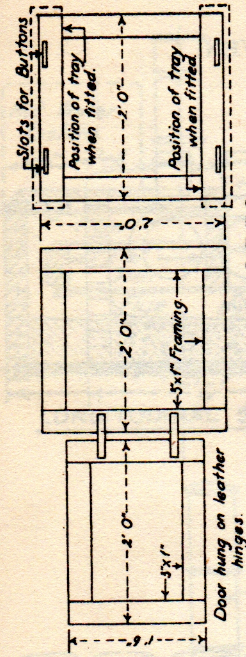
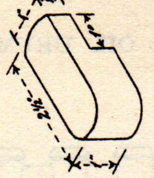

2'-8"
Outlet
A
A
2"x1"
1"x1" ledges
11"
Plan
out of 6"x1"
Lid of 6"x1"
Lid 6"x1"
3"x1" Batt
Biscuit tin bottom Perforated
Outlet Tin
11"
3"
1'-4"
Section A.A.
Biscuit Tin
Outlet
1'-4"
1'-1"
End Elevation

Fig. 4.

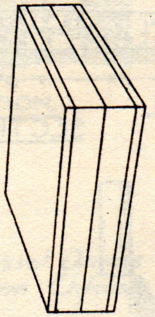
PORTABLE FLY-PROOF MEAT SAFE.


Slots for Buttons
Position of tray when fitted.
Position of tray when fitted
2'0"
2'0"
2'0"
5"x1" Framing
2'0"
3"x1"
Door hung on leather hinges.
1'6"

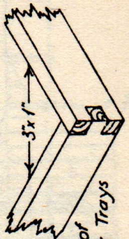
DETAIL OF SIDES



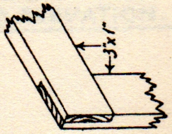
Detail of Button.
¼ Full Size.



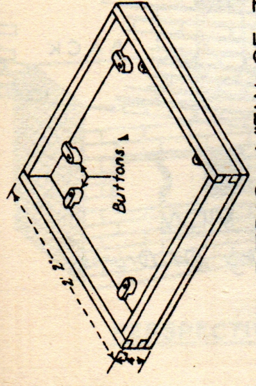
Safe closed for Transport



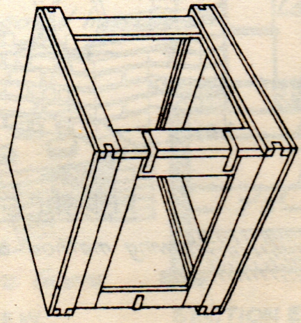
Detail of Joint for Trays



Detail of Joint for Framing

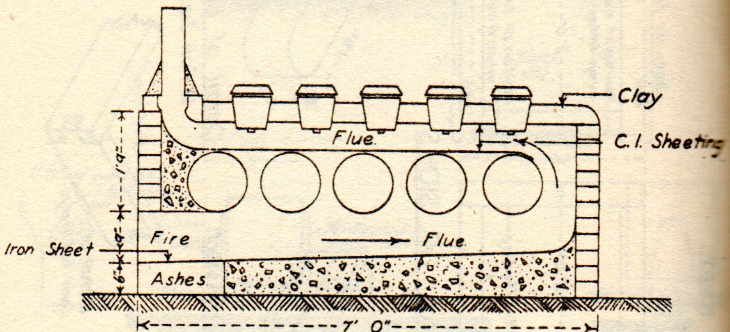


ISOMETRIC VIEW OF TRAY

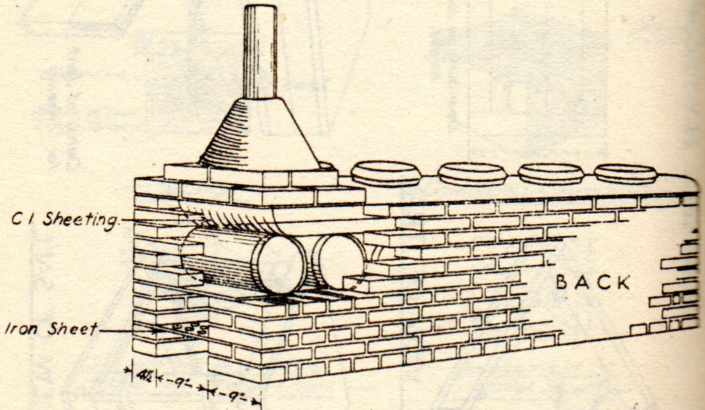


PERSPECTIVE VIEW OF SAFE

OIL DRUM OVEN.


Clay
C.I. Sheeting
Flue
1'9"
9"
6"
Iron Sheet
Fire
Flue
Ashes
7' 0"

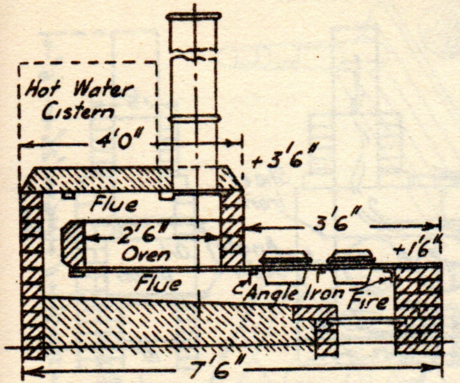
SECTION


C I Sheeting
BACK
Iron Sheet
4½
9"
9"

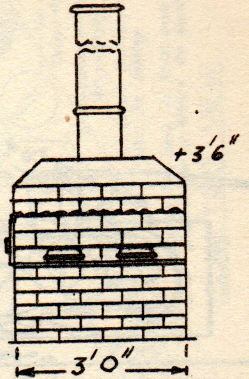
PERSPECTIVE VIEW.

Showing method of fixing Oil Drums

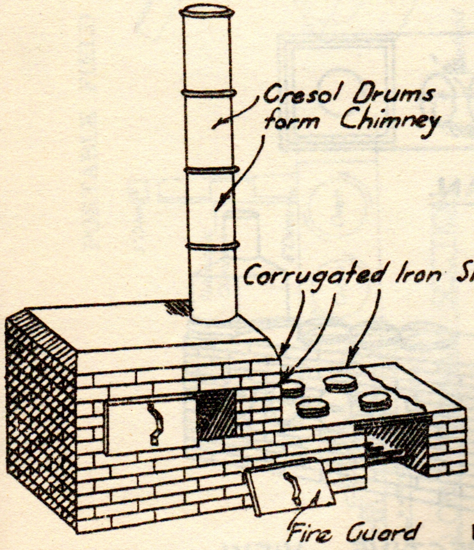
COOKER FOR CAMPS AND BILLETS.


Hot Water Cistern
4'0"
+3'6"
Flue
2'6"
Oven
3'6"
+1'6"
Flue
Angle Iron
Fire
7'6"

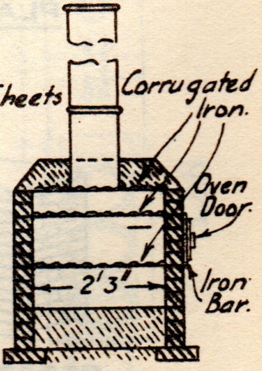
LONGITUDINAL SECTION.



END ELEVATION.

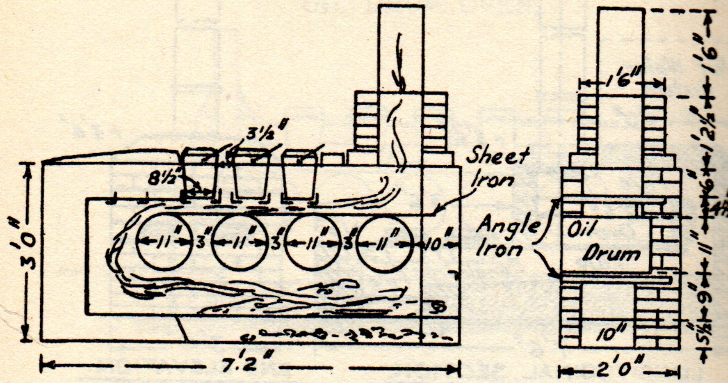

Cresol Drums form Chimney
Corrugated Iron Sheets
Fire Guard

PERSPECTIVE VIEW.

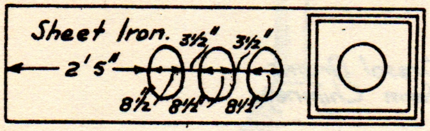

Corrugated Iron.
Oven Door.
Iron Bar.
2'3"

SECTION E.F.

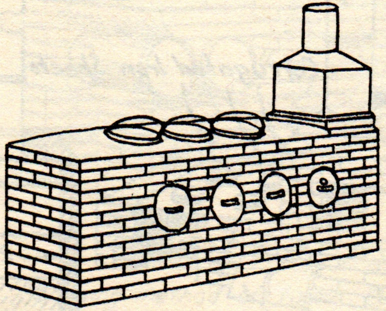
CAMP COOKER.


3½"
8½"
Sheet Iron
Angle Iron
Oil Drum
3'0"
11"
3"
11"
3"
11"
3"
11"
10"
7'2"
1'6"
1'6"
1'2½"
6"
4½"
11"
9"
5½"
10"
2'0"

SECTIONS.

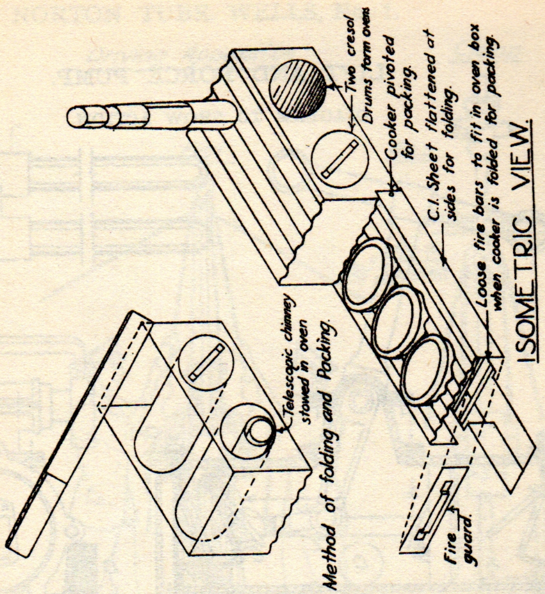

Sheet Iron.
3½"
3½"
2'5"
8½"
8½"
8½"

PLAN.



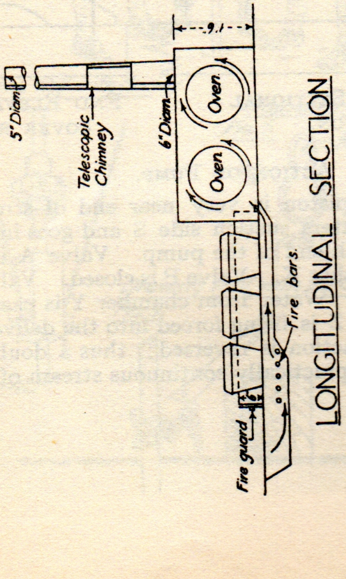
PERSPECTIVE VIEW.

PORTABLE FIELD KITCHEN.

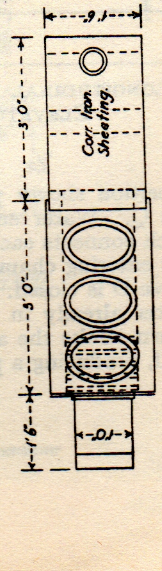

Two cresol Drums form ovens
Cooker pivoted for packing.
C.I. Sheet flattened at sides for folding.
Loose fire bars to fit in oven box when cooker is folded for packing.
Fire guard.
Telescopic chimney stowed in oven

Method of folding and Packing.

ISOMETRIC VIEW.


1'6"
5" Diam
6" Diam
Telescopic Chimney
Oven
Oven
Fire bars.
Fire guard
Fire guard

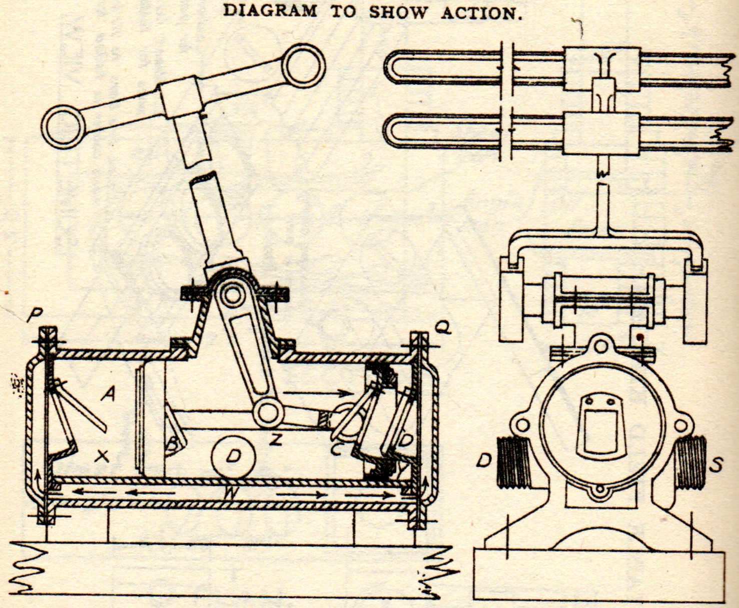
LONGITUDINAL SECTION


1'6"
5'0"
5'0"
1'6"
Corr. Iron Sheeting.
1'0"

PLAN

LIFT AND FORCE PUMP.

DIAGRAM TO SHOW ACTION.


P
Q
A
X
B
Z
D
C
D
W
D
S

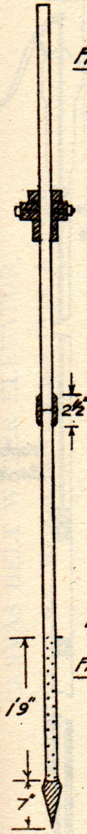
LONGITUDINAL SECTIONAL ELEVATION.

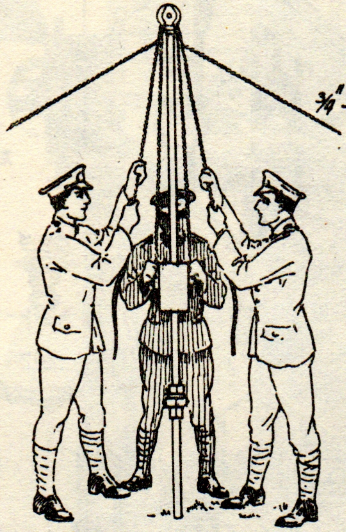
END ELEVATION WITH COVER REMOVED.

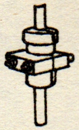
ACTION OF PUMP.

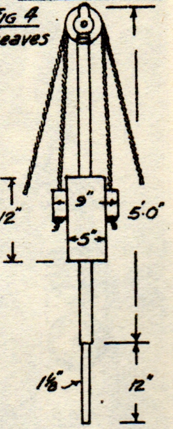
In position shown piston is very near end of stroke moving towards Q. Water enters suction side S and goes into chamber W, which connects each end of the pump. Valve A is open and water is entering chamber X, Valve B is closed. Valve C is open and valve D is closed. Water from chamber Y is passing into Z and water already in Z is being forced into the delivery D. On the return stroke the action is reversed; thus a double action is obtained, producing a practically continuous stream of water.

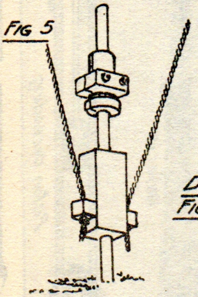
NORTON TUBE WELLS, No. 1.

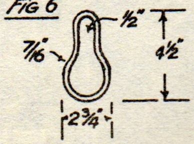

Section of Well
Fig 2
2½"
1'9"
7"

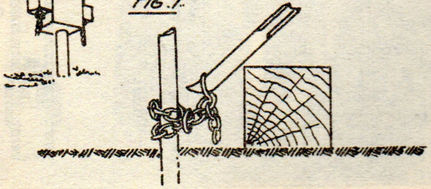

Driving Apparatus
Fig 1



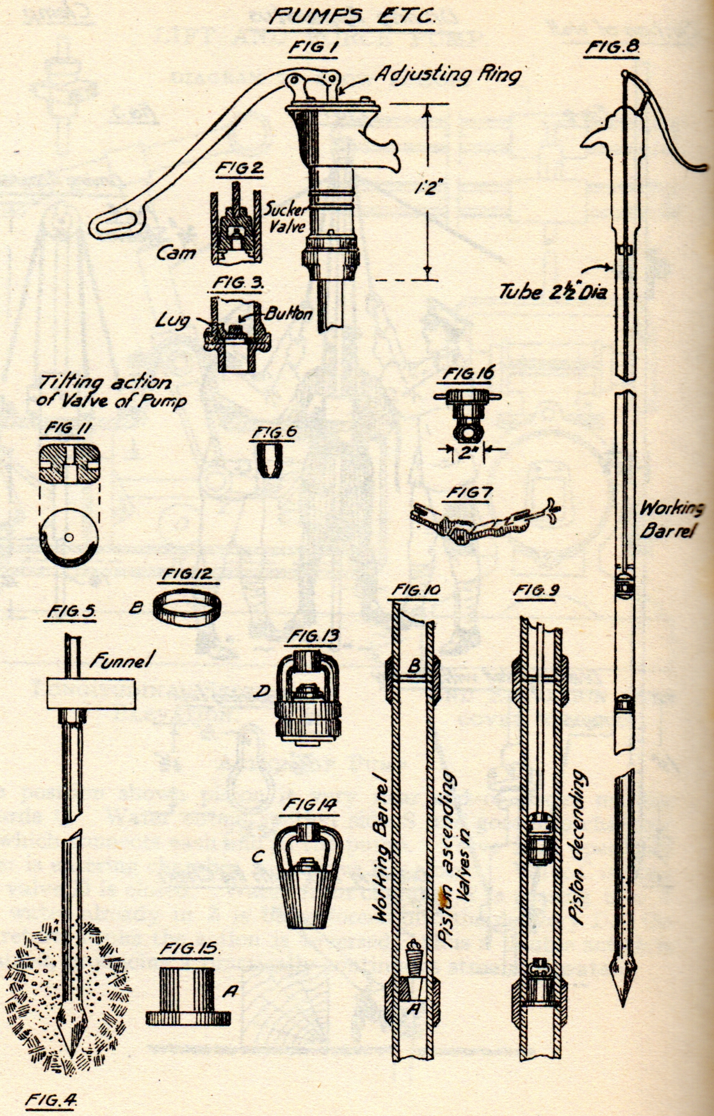

Driving Apparatus
Fig 4
¾" Sheaves
12"
9"
5"
5'0"
1⅛"
12"

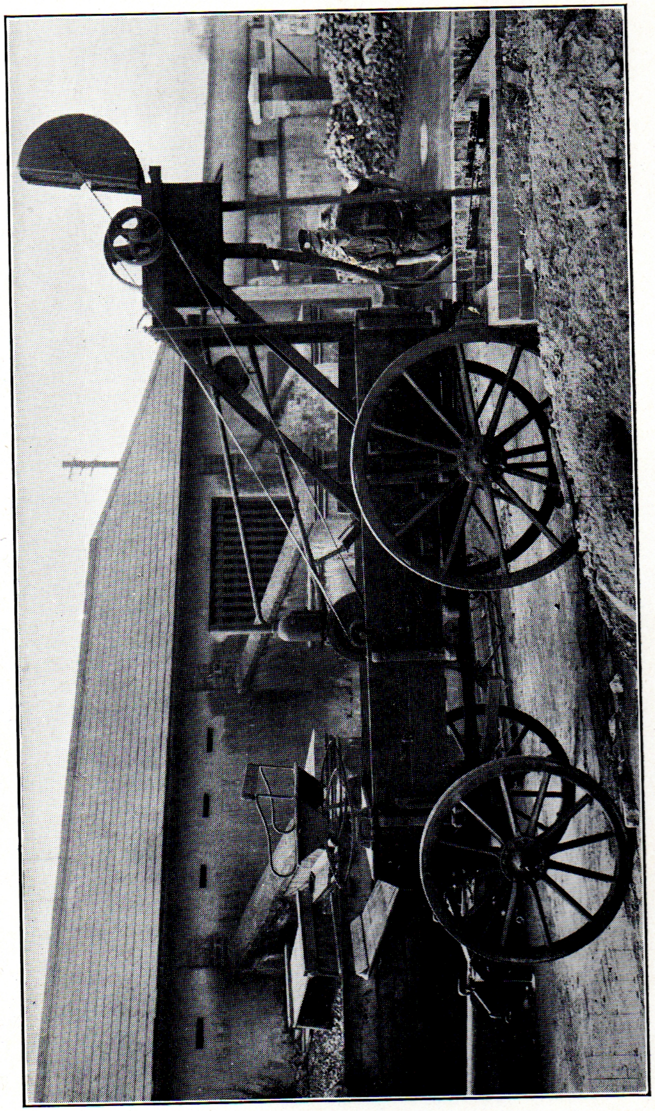

Drawing Well with Monkey
Fig 5


Stoppering Link
Fig 6
½"
7/16"
4½"
2¾"


Drawing Well with the Chain
Fig 7

NORTON TUBE WELLS, No. 2.


PUMPS ETC.
FIG 1
Adjusting Ring
1'2"
FIG 2
Sucker Valve
Cam
FIG. 3.
Lug
Button
Tilting action of Valve of Pump
FIG 11
FIG 6
FIG 16
2"
FIG 7
FIG 8
Tube 2½" Dia
Working Barrel
FIG 12
B
FIG 5
Funnel
FIG 13
D
FIG 14
C
FIG 15
A
FIG 10
B
Working Barrel
Piston ascending Valves in
A
FIG 9
Piston decending
FIG 4



CANVAS BELT WATER ELEVATOR.

MOUNTED ON G.S. WAGON IN POSITION OVER A WELL.

AQUATOLE ELEVATOR

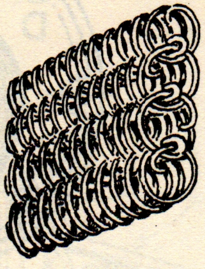


Fig. 1

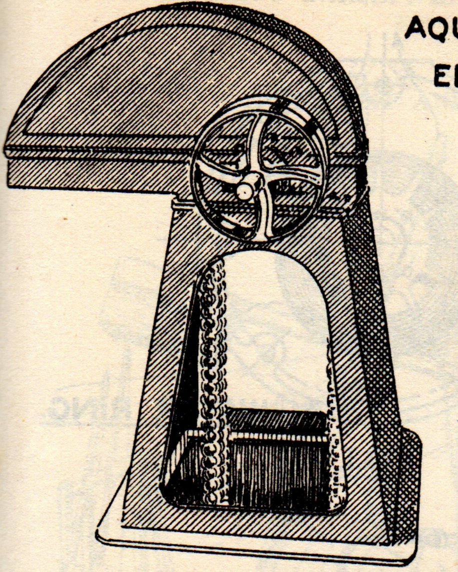


Fig. 2.

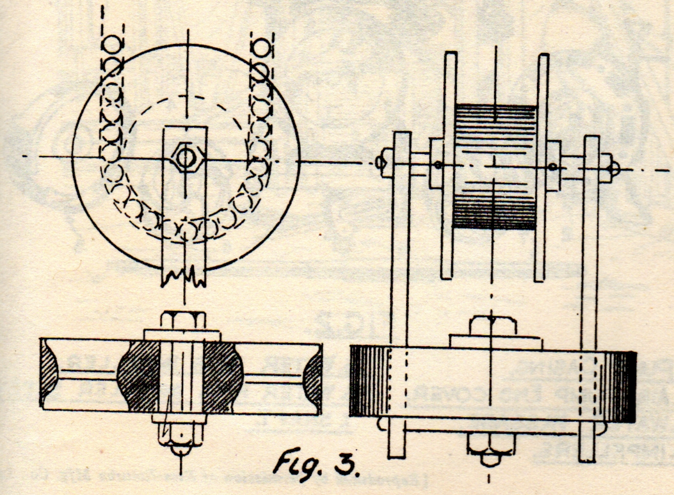


Fig. 3.

REES-ROTURBO SELF-PRIMING PUMP DISMANTLED.

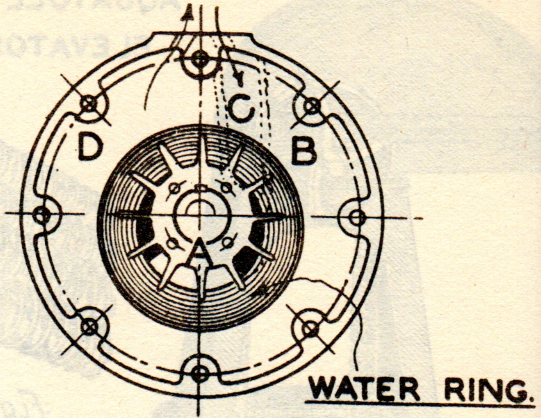


FIG.1.

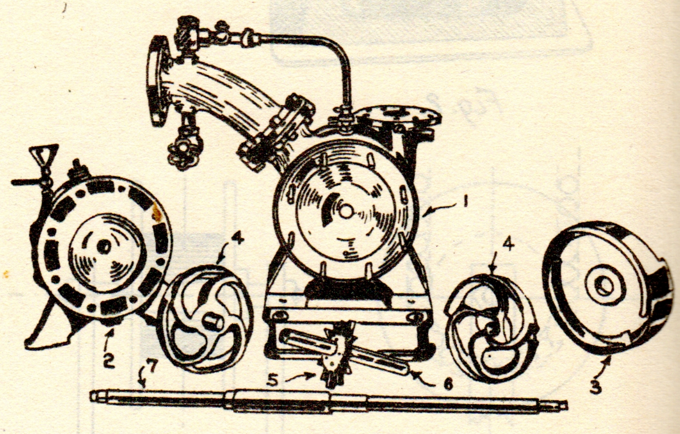
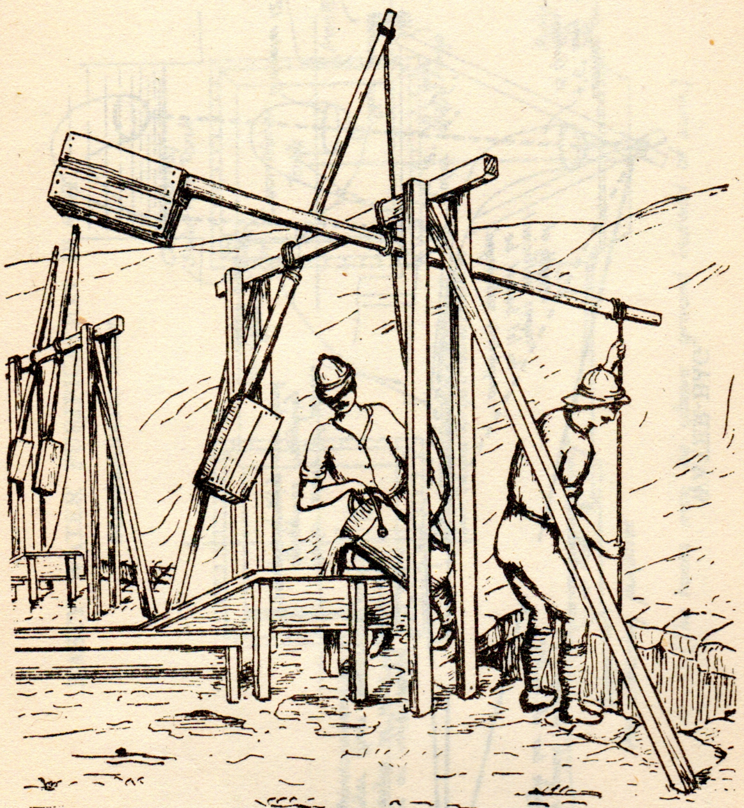


FIG.2.

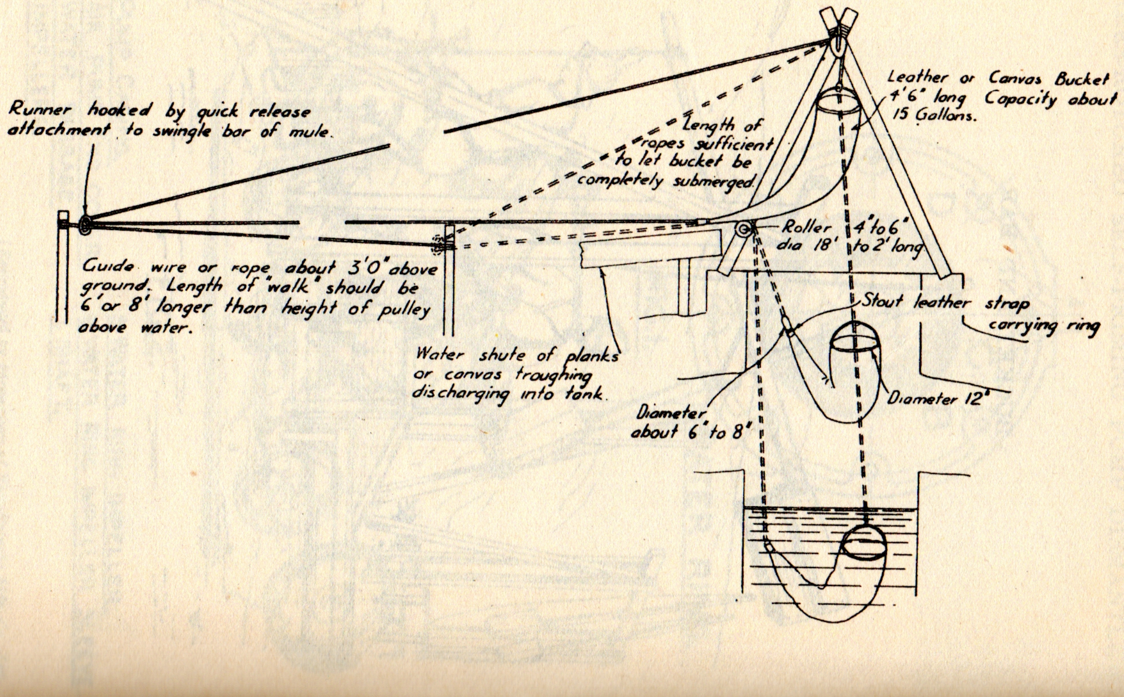
1 PUMP CASING.
2. AIR PUMP END COVER.
3. WATER PASSAGE.
4. IMPELLERS.
5. WATER RING IMPELLER.
6. WATER RING IMPELLER SLEEVE.
7. SHAFT.

[*Reproduced by permission of Rees-Roturbo Mfg. Co., Ltd.*

BUCKET AND BAR.

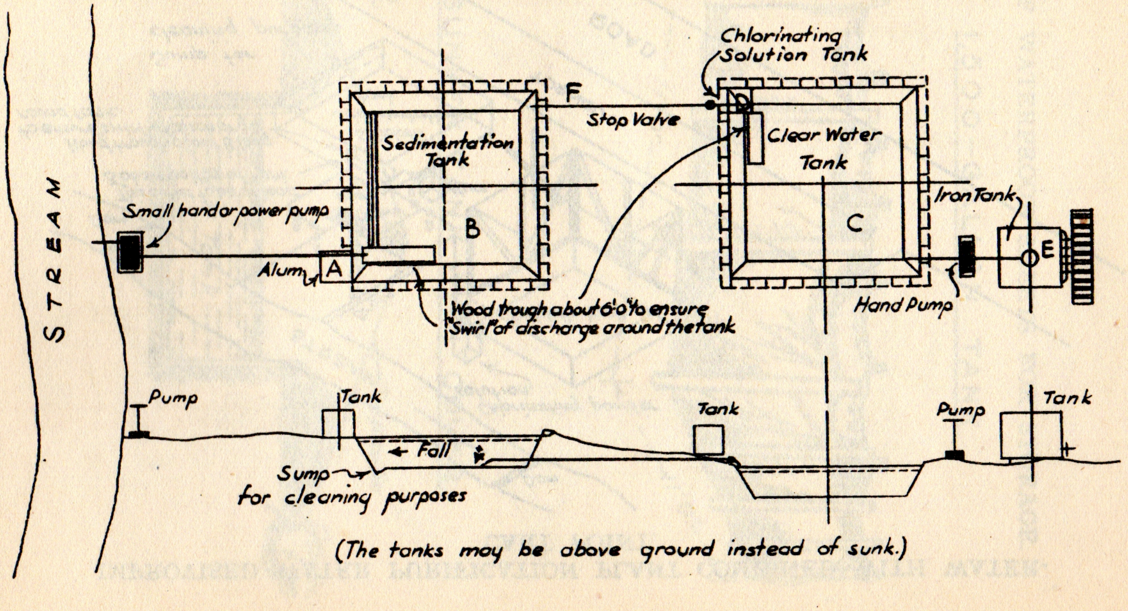


WATER-BAG.


Runner hooked by quick release attachment to swingle bar of mule.
Guide wire or rope about 3'0" above ground. Length of "walk" should be 6' or 8' longer than height of pulley above water.
Length of ropes sufficient to let bucket be completely submerged.
Leather or Canvas Bucket 4'6" long Capacity about 15 Gallons.
Roller dia 18' 4" to 6" to 2' long
Water shute of planks or canvas troughing discharging into tank.
Stout leather strap carrying ring
Diameter about 6" to 8"
Diameter 12"

HASTY WATER PURIFICATION PLANT.

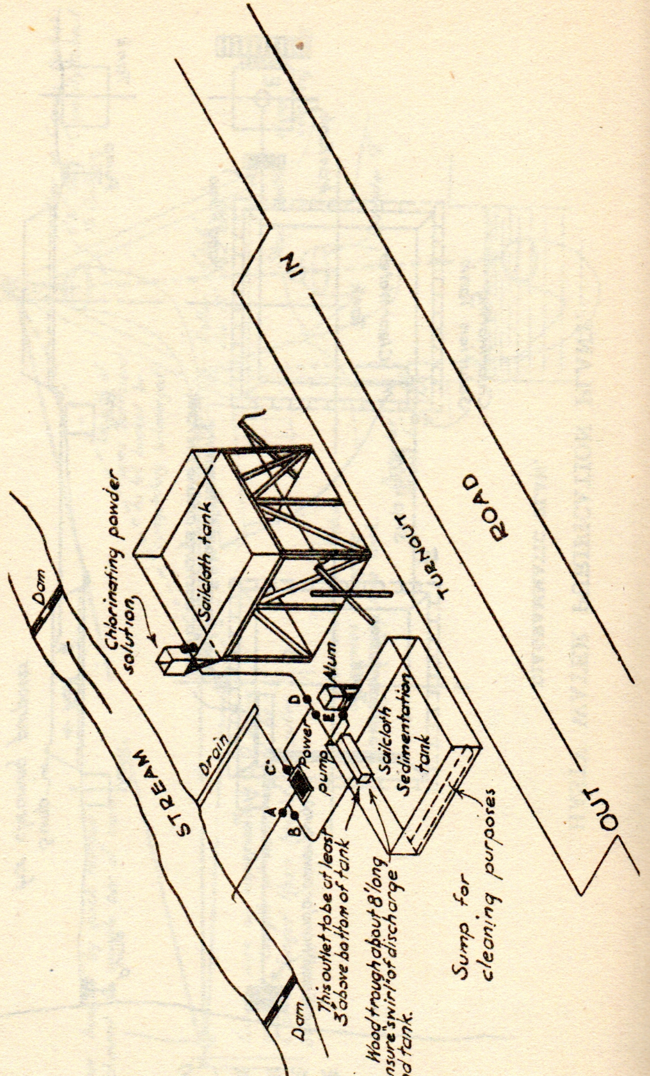
DIAGRAMMATIC PLAN.


STREAM
Small hand or power pump
Alum
A
Sedimentation Tank
B
F
Stop Valve
Chlorinating Solution Tank
Clear Water Tank
C
Iron Tank
E
Hand Pump
Wood trough about 6'0" to ensure "Swirl" of discharge around the tank
Pump
Tank
Fall
Sump for cleaning purposes
Tank
Pump
Tank

(The tanks may be above ground instead of sunk.)

[*Ref. Secs.* **130**, 9; **133**, 3.

IMPROVISED WATER PURIFICATION PLANT COMBINED WITH WATER-CART POINT.

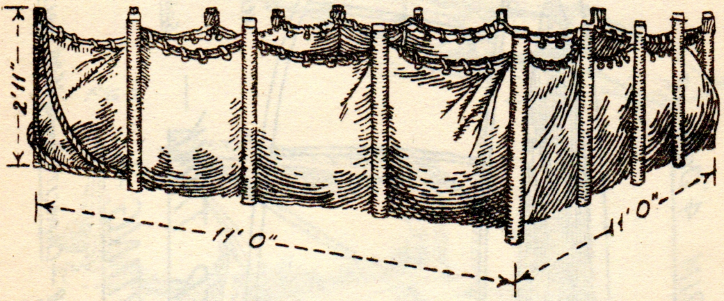

Dam
Chlorinating powder solution
Sailcloth tank
Alum
D
E
Power pump
C
A
B
Drain
STREAM
Sailcloth Sedimentation tank
Sump for cleaning purposes
This outlet to be at least 3" above bottom of tank
Wood trough about 8' long to ensure "swirl" of discharge round tank.
Dam
IN
TURNOUT
ROAD
OUT

Ref. Sec. **132**, 1, 3 *and* 9.]

USE OF WATERPROOF SHEETS FOR STORAGE.

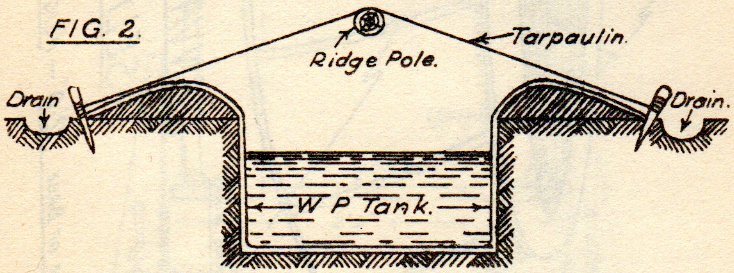
1,500-GALLON TANK

FIG. 1.

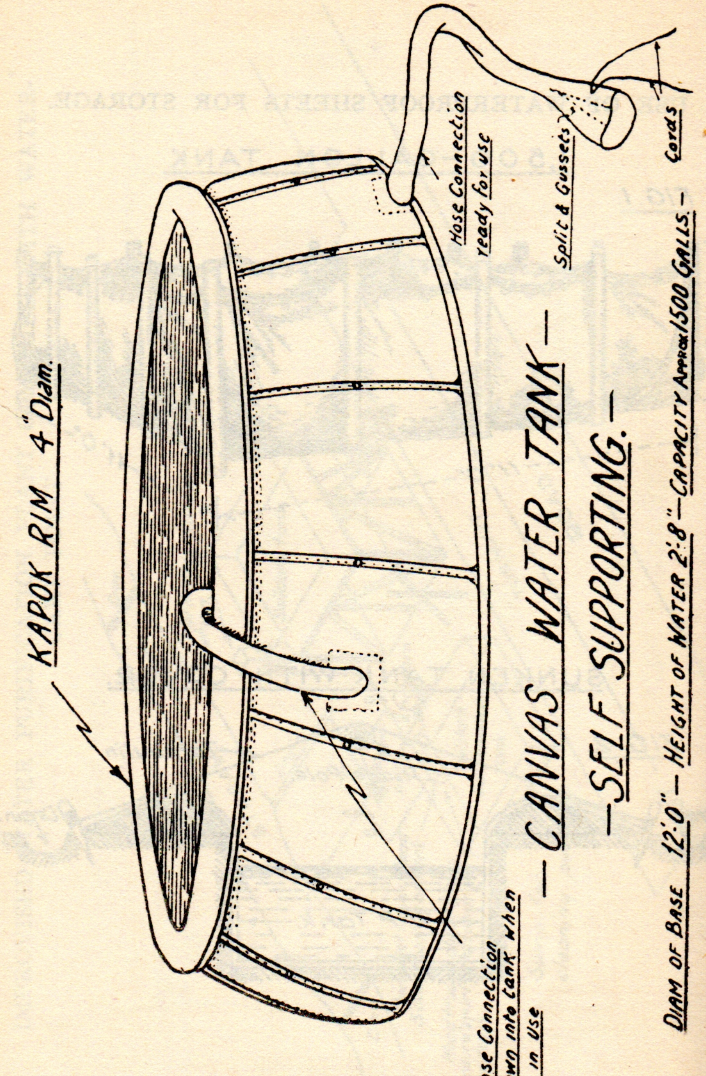


SUNKEN TANK WITH COVER.

FIG. 2.


Ridge Pole.
Tarpaulin.
Drain
Drain.
W P Tank.

[*Ref. Sec.* **132**, 1 *and* 3.


KAPOK RIM 4" Diam.
Hose Connection ready for use
Split & Gussets
Cords
Hose Connection thrown into tank when not in use

— CANVAS WATER TANK —

— SELF SUPPORTING. —

DIAM OF BASE 12'0" — HEIGHT OF WATER 2'8" — CAPACITY APPROX 1500 GALLS. —

Ref. Sec. **132**, 1 *and* 4.]

TROUGH WATERPROOF.

(ACTUAL CAPACITY 350 GALLONS.)

FIG. 1

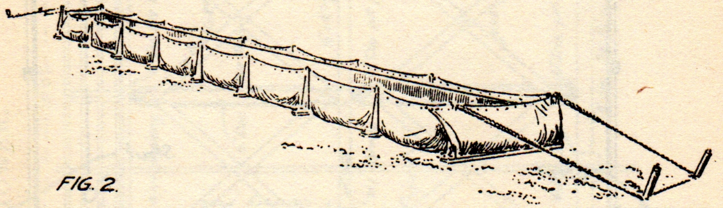


FIG. 2

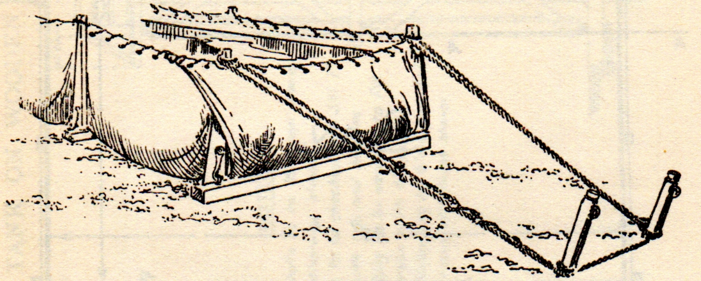


FIG. 3. STANDARD MARK II *for* Trough waterproof 600 Gallons

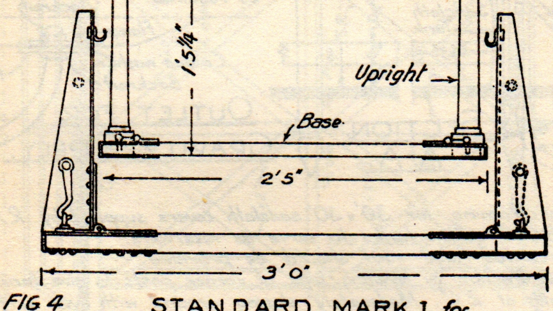
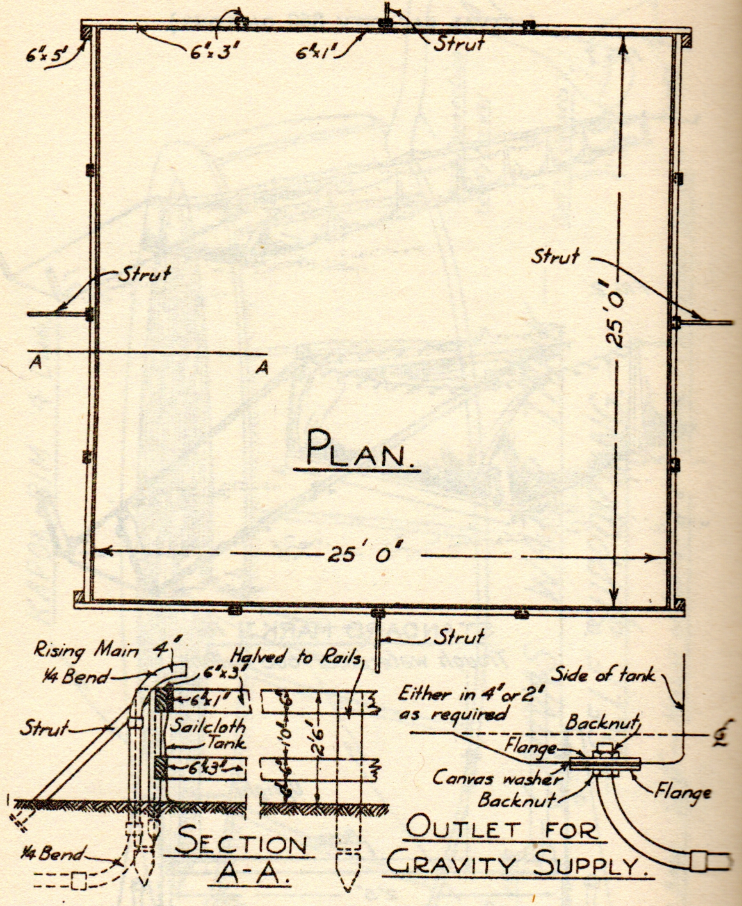

1'5¼"
Upright
Base
2'5"
3'0"

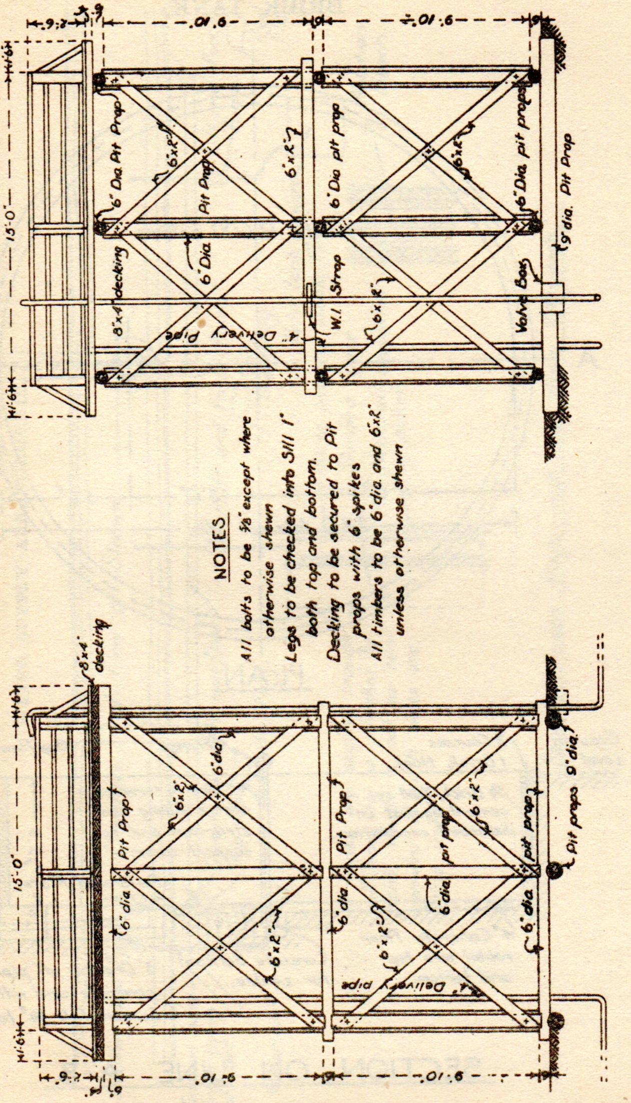
FIG 4 STANDARD MARK 1 *for* Trough waterproof 600 Gallons

GROUND LEVEL FRAMED 8,000-GALLON TANK.


6"x5'
6"x3'
6"x1'
Strut
Strut
Strut
A
A
25' 0"
PLAN.
25' 0"
Strut
Rising Main 4"
1/4 Bend
Halved to Rails
6"x3"
6"x1'
Strut
Sailcloth Tank
6"x3'
10"
2'6"
SECTION A-A.
1/4 Bend
Either in 4" or 2" as required
Side of tank
Backnut
Flange
Canvas washer
Backnut
Flange
OUTLET FOR GRAVITY SUPPLY.

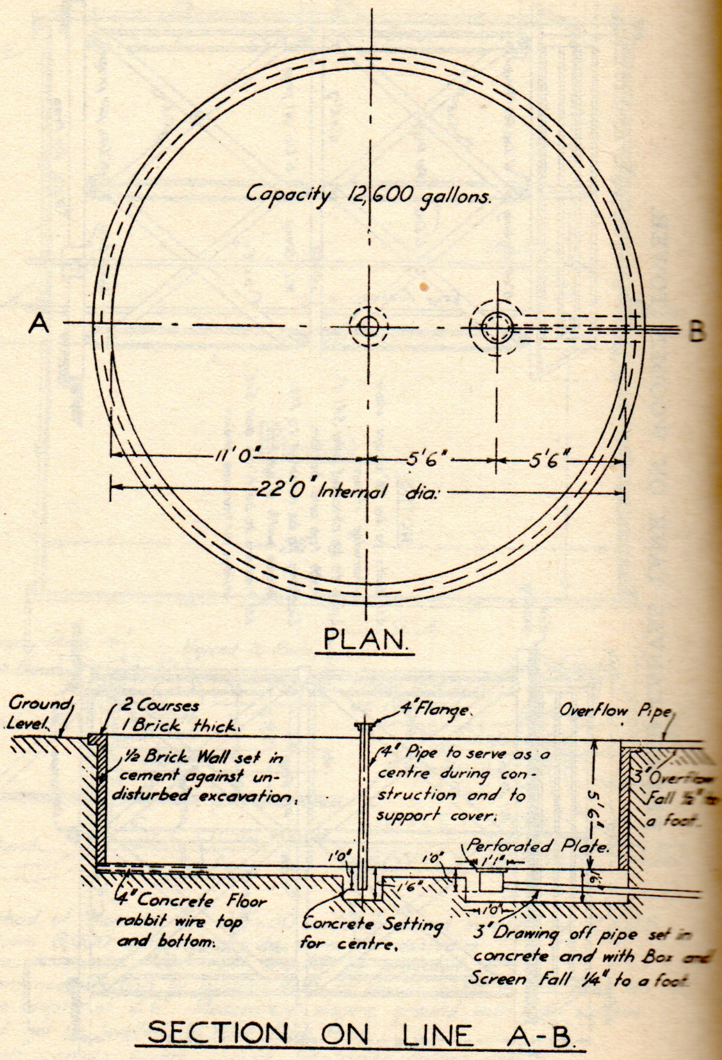
Method of framing for 30'x30' sailcloth covers supplied by R.A.O.D. to form 8,000 gallon tanks to serve as reservoirs.
A rough canvas ridge roof should be provided.
Commence erection by levelling tops of corner posts to give tank an average depth of 2'6". Moderately sloping ground with even surface need not be levelled to take tank floor.
Green canvas covers should be tarred before use.

FRAMED CANVAS TANK ON WOODEN TOWER.


9'10"
9'10"
15'0"
6" Dia Pit Prop
6"x2"
Pit Prop
6"x2"
6" Dia pit prop
6"x2"
6" Dia. pit prop
Pit Prop
8"x4" decking
6" Dia
W.I. Strap
6"x2"
Valve Box
9" dia. Pit Prop
4" Delivery Pipe
8"x4" decking
Pit Prop
6" dia
6"x2"
Pit Prop
6" dia
pit prop
6"x2"
pit prop
Pit props 9" dia.
6" dia
6"x2"
6" dia
6" dia
6"x2"
4" Delivery pipe
15'0"

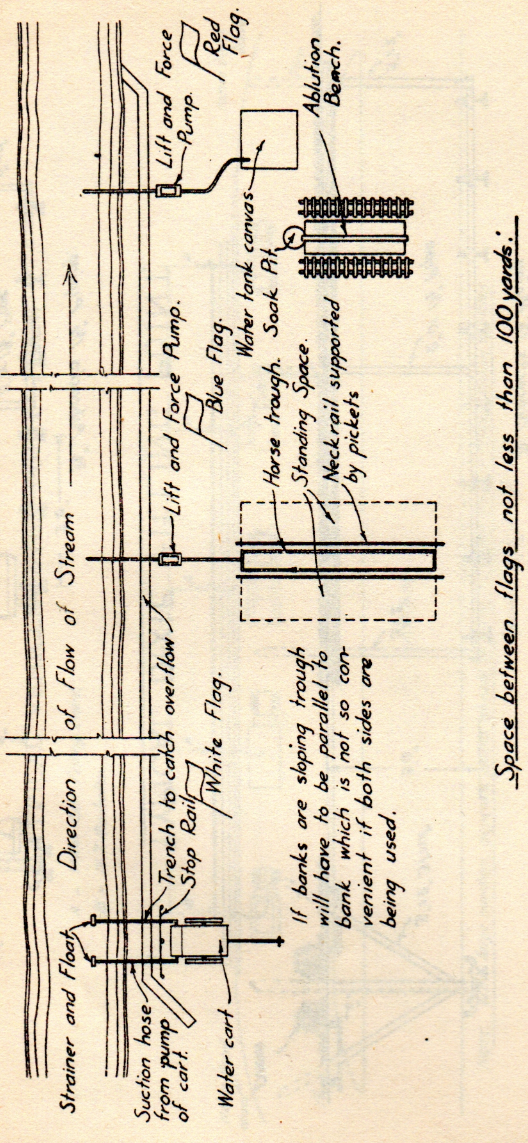
NOTES
All bolts to be 5/8" except where otherwise shewn
Legs to be checked into Sill 1" both top and bottom.
Decking to be secured to Pit props with 6" spikes
All timbers to be 6" dia. and 6"x2" unless otherwise shewn

BRICK TANK.

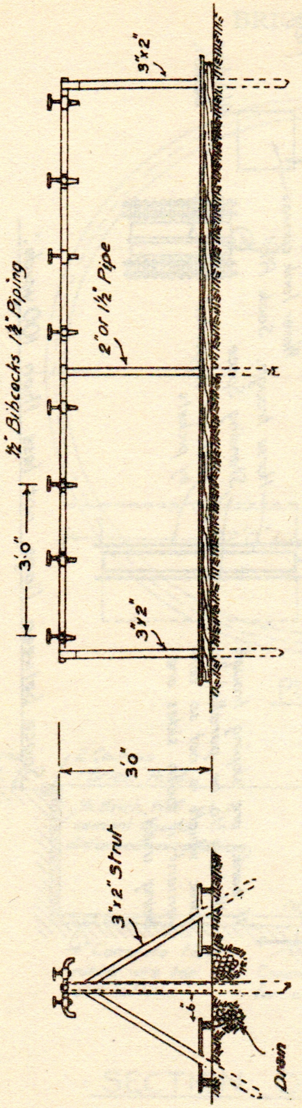

Capacity 12,600 gallons.
A
B
11'0"
5'6"
5'6"
22'0" Internal dia.
PLAN.
Ground Level.
2 Courses 1 Brick thick.
4" Flange.
Overflow Pipe
½ Brick Wall set in cement against undisturbed excavation.
4" Pipe to serve as a centre during construction and to support cover.
5'6"
3" Overflow Fall ½" to a foot.
Perforated Plate.
1'0"
1'0"
1'1"
1'6"
9"
1'0"
4" Concrete Floor rabbit wire top and bottom.
Concrete Setting for centre.
3" Drawing off pipe set in concrete and with Box and Screen Fall ¼" to a foot.
SECTION ON LINE A-B.

CAMP FOR SMALL UNIT FOR 1 OR 2 NIGHTS.

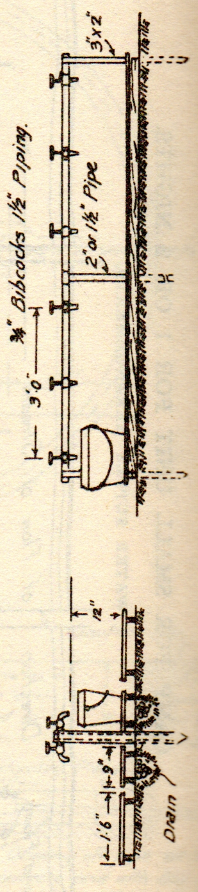
WATER SUPPLY ARRANGEMENTS.


Direction of Flow of Stream
Strainer and Float.
Suction hose from pump of cart.
Water cart
Trench to catch overflow
Stop Rail
White Flag.
Lift and Force Pump.
Blue Flag.
Lift and Force Pump.
Red Flag.
Horse trough.
Standing Space.
Neckrail supported by pickets
Water tank canvas.
Soak Pit.
Ablution Bench.
If banks are sloping trough will have to be parallel to bank which is not so convenient if both sides are being used.
Space between flags not less than 100 yards.

TYPICAL WATER-BOTTLE FILLING POINT.

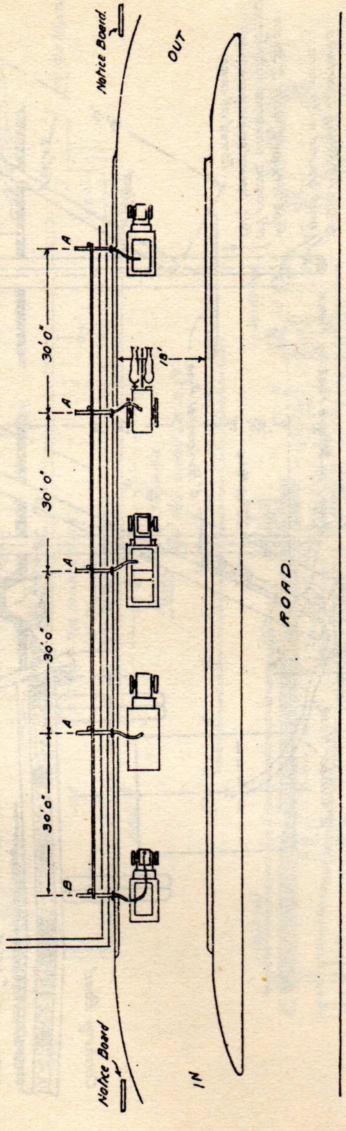

3"x2"
½" Bibcocks 1½" Piping
2" or 1½" Pipe
3'0"
3"x2"
3'0"
3"x2" Strut
6"
Drain

TYPICAL DIXIE FILLING POINT.


3"x2"
¾" Bibcocks 1½" Piping
2" or 1½" Pipe
3'0"
12"
1'6"
9"
Drain

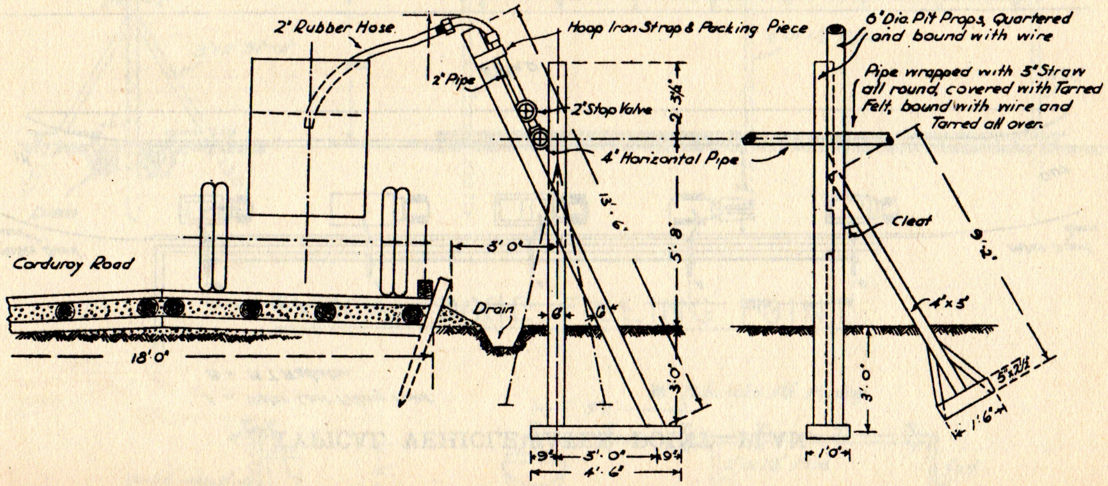
TYPICAL VEHICLEWATER POINT—PLAN.

A – Water Cart Filling Point.
B – M.T. Radiator.


Notice Board
OUT
A
30'0"
18'
A
30'0"
A
30'0"
A
30'0"
B
ROAD
IN
Notice Board

NOTE. With large numbers, separate points should be made for motor drawn & Animal drawn vehicles.

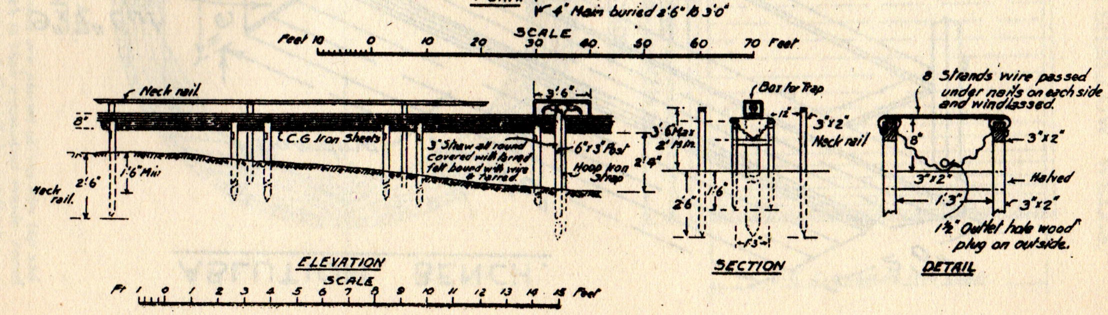
TYPICAL VEHICLE WATER POINT DETAIL.


2" Rubber Hose
Hoop Iron Strap & Packing Piece
6" Dia. Pit Props, Quartered and bound with wire
2" Pipe
2" Stop Valve
2' 3½"
4" Horizontal Pipe
Pipe wrapped with 5" Straw all round, covered with Tarred Felt, bound with wire and Tarred all over.
Cleat
9' 2"
13' 6"
5' 8"
3' 0"
Corduroy Road
Drain
6"
4" x 5"
3" x 2½"
1' 6"
18' 0"
3' 0"
9"
5' 0"
9"
4' 6"
1' 0"

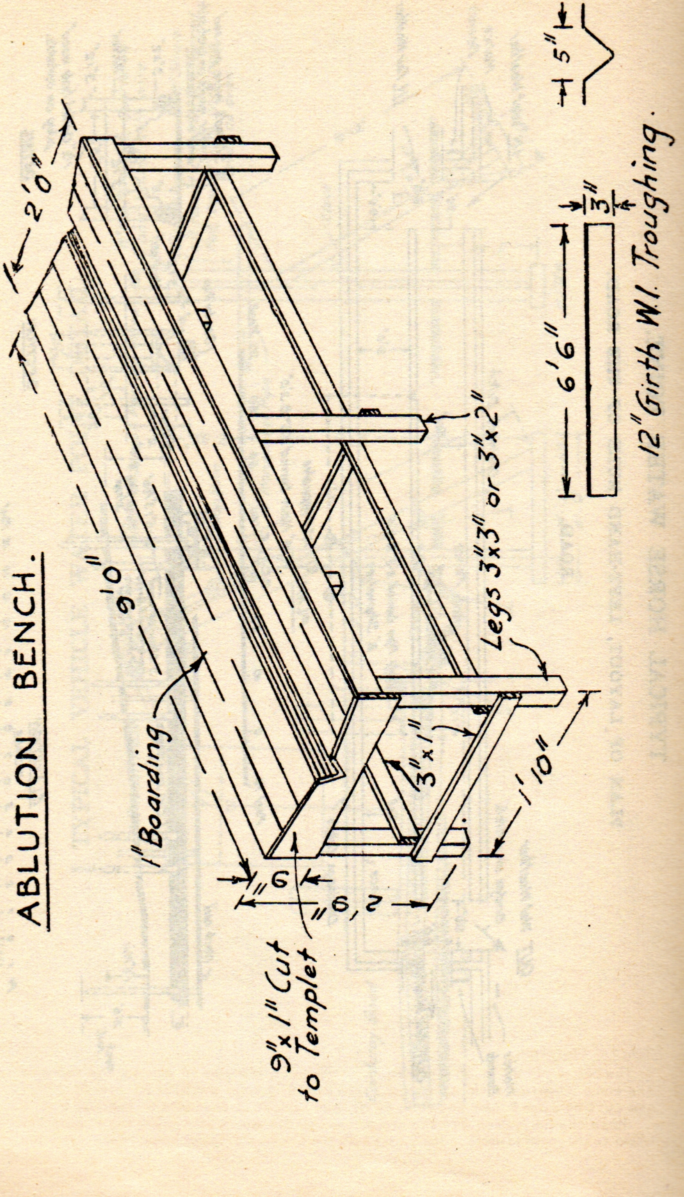
TYPICAL HORSE WATER POINT.

PLAN OF LAYOUT, LEFT-HAND RULE OF THE ROAD.

ROAD.


OUT Wet Weather
Notice Boards
Bridge over ditch.
Drainage Ditch
IN Wet Weather
Notice Boards
9' 0"
1' 0"
30' 0" or other suitable length
Fence
Fall
OUT Fair Weather
IN Fair Weather
2" Supply Pipe buried 2' 6" to 3' 0"
Fence
2" Stopvalves
9' 0"
Drainage Ditch
PLAN.
4" Stopvalve
4" Main buried 2' 6" to 3' 0"
SCALE
Feet 10 0 10 20 30 40 50 60 70 Feet
Neck rail
8"
C.G. Iron Sheets
3" Straw all round covered with tarred felt bound with wire & tarred.
3' 6"
6" x 3" Post
Hoop Iron Strap
1' 6" Min
2' 6"
Neck rail.
3' 6" Max
2' Min.
2' 4"
1' 6"
2' 6"
Box for Trap
12"
3" x 2" Neck rail
1' 3"
8 Strands wire passed under nails on each side and windlassed.
8"
3" x 2"
Halved
1' 3"
1½" Outlet hole wood plug on outside.
ELEVATION
SCALE
Ft 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet
SECTION
DETAIL

ABLUTION BENCH.


2'0"
9'0"
1" Boarding
9"x1" Cut to Templet
2'6"
9"
1'10"
3"x1"
Legs 3"x3" or 3"x2"
6'6"
5"
3/4"
12" Girth W.I. Troughing.

TUBBING FOR SINKING SHALLOW WELLS.

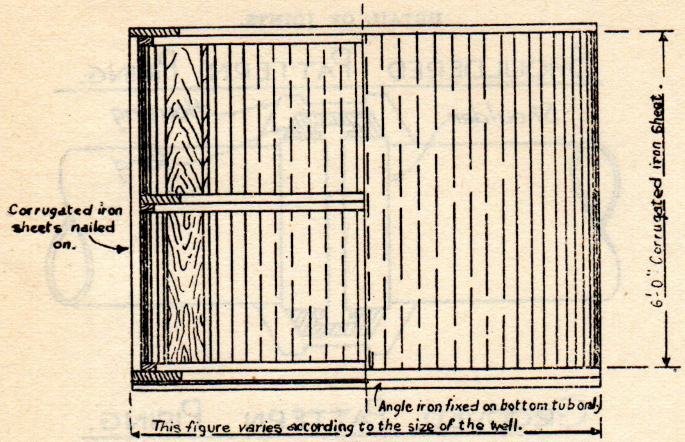

Corrugated iron sheets nailed on.
6'0" Corrugated iron sheet.
Angle iron fixed on bottom tub only.
This figure varies according to the size of the well.

FIG. 1. ELEVATION.

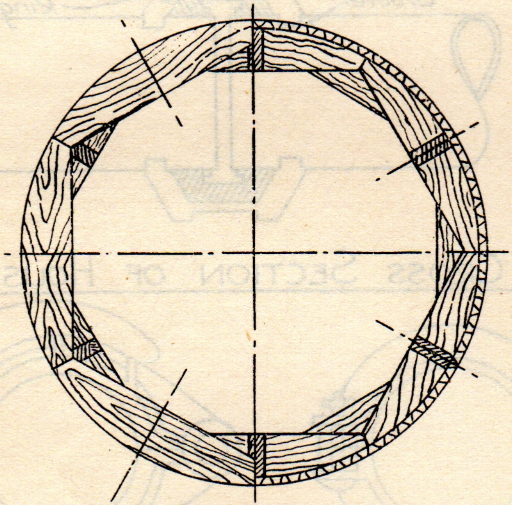


FIG. 2. PLAN.

Method of Operation.

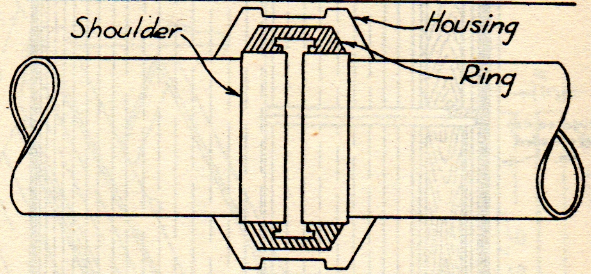
The tub is placed in an excavation. Two rails are placed across the top and the ends weighted with sandbags. The earth is then excavated inside round the cutting edge & the tub falls by its own weight & that of the sandbags.

When the tub is flush with the ground, another tub is bolted on top and the process continued to the required depth. The frames & studs are made with timber of available scantlings.

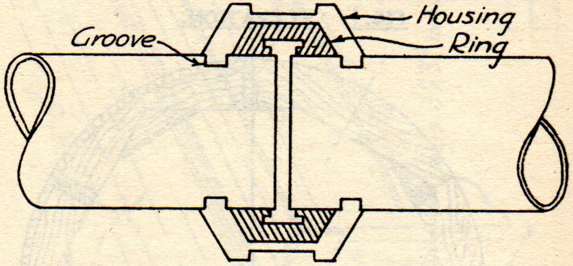
VICTAULIC PIPING.

DETAIL OF JOINTS.

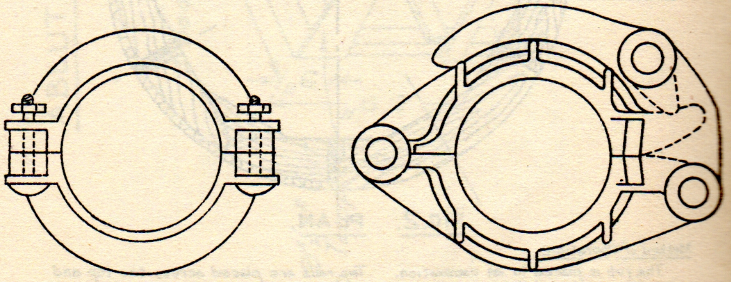
SHOULDERED PATTERN PIPING.


Shoulder
Housing
Ring

GROOVED PATTERN PIPING.


Housing
Groove
Ring

CROSS SECTION OF HOUSING.



Old Pattern. *New Pattern.*